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Silverleaf Whitefly

1995 Supplement to the 5-Year National Research and Action Plan

(Formerly Sweetpotato Whitefly, Strain B)
Third Annual Review Held in San Diego, California, January 28-31,1995

In cooperation with—

USDA/Agricultural Research Service

USDA/Cooperative State Research, Education, and Extension Service

State Agricultural Experiment Stations

USDA/Animal and Plant Health Inspection Service

USDA/Extension Service

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Contents

Editors' Comments

Annual progress reviews of the multi-agency silverleaf whitefly (formerly sweetpotato whitefly Strain B) research and action plan were conducted at Tempe, AZ, 18-21 January 1993 and Orlando, FL, 24-27 January 1994. The enclosed compilation of abstracts from the third annual progress review at San Diego, CA, 28-31 January 1995 represents the continuing efforts of the federal and state agencies and agricultural industries efforts to develop effective tools for whitefly management. In the present report some authors have used sweetpotato whitefly *Bemisia tabaci* (Gennadius) Strain B in lieu of the newly described silverleaf whitefly, *B. argentifolii* Bellows and Perring, species. The editors, for the purpose of this report, assume the two names are synonymous. The editors appreciate the contributions of all attendees and participants. The research reports herein are in the form of summaries of current state-of-the-art studies designed to provide a knowledge base for development of economic, environmentally compatible and socially acceptable whitefly management systems. The abstract contents remain the sole responsibility of the authors. Other sections of this document are the combined effort of the meeting participants and other interested contributors. Minor editing was done only to conform to camera-ready format requirements. Tables A through F of the "Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly" have been reproduced and included in the present supplement. This is for the reader's orientation and relevance of the third year review to the plan in its entirety. Also included in the present publication is an extensive whitefly bibliography for the use of scientists, administrators and others seeking whitefly information.

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The USDA SPW Coordinating Group, Annual Review Program Chairs, Section Chairs, Local and State Coordinators and the Technical Committee sincerely appreciate the contributions of all the participants and those who have helped in organizing the meeting. We especially thank Lisa Arth, Cindy Giorgio, Lynn Jech, Marilyn Reega and Gail Smith for their help in assuring the success of the meeting.

Foreword

During 1991 and 1992 representatives of several USDA agencies, State Agricultural Experiment Stations and commodity-involved industries met to develop a comprehensive 5-Year National Research and Action Plan for control and management of the sweetpotato whitefly (SPW). Meetings were held in Atlanta, GA, Reno, NV and Houston, TX which resulted in the establishment of the six research and action areas. Additionally, in 1992, a USDA Sweetpotato Whitefly Research, Education and Implementation Coordinating Group (two members from ARS, two members from APHIS, two members from CSRS/SAES, and one member from ES) was formed to coordinate the USDA interagency activities. The USDA Coordinating Group and partner State Agricultural Experiment Stations help ensure a unified effort for the plan and to provide for an annual review to exchange research information, plan cooperative work, and evaluate research progress.

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius), has been an economic pest in the United States and worldwide for many years. However, the expanded host range involved in the current whitefly outbreaks, as well as biological, genetic and vector differences and the occurrence of unique adverse plant physiological disorders in some cultivated crops led several scientists to propose the occurrence of a new SPW biotype (Strain B). Subsequently, SPW Strain B was described as a new species *Bemisia argentifolii* Bellows and Perring, and renamed the silverleaf whitefly (SLW). Although the transition from SPW- to SLW-dominated agricultural systems in Arizona, California, Texas and Florida is not, at present, clearly defined, it appears to have occurred during the mid to late 1980's. Current economic losses from SLW infestations include losses to a wide range of ornamentals and vegetable crops. Outbreaks of the SLW in California, Arizona, Texas and Florida, resulted in conservative estimates in 1991 and 1992 of losses in the agricultural communities affected that exceeded \$200 and \$500 million, respectively. Crop yield losses attributable to SLW in the Imperial Valley over a 3-year period (Fall 1991 to April 1994) have been estimated to be about \$336 million.

Development of the 5-Year National Research and Action Plan and the subsequent annual progress reviews in 1993, 1994 and 1995 have been through the combined efforts of all participating Federal and State agencies and the agricultural industries in response to an urgent need for management technologies to reduce losses in agricultural communities where the SLW is a factor in crop and horticultural production. Significant progress has been made and a number of suppression technologies and strategies are on-line, or coming on-line, as a result of the highly unified effort.

The members of the USDA Sweetpotato Whitefly Research, Education and Implementation Coordinating Group are deeply appreciative for the contributions of all of the individuals who have made the progress reviews and 5-Year SLW Research and Action Plan a successful endeavor. Special appreciation this year is accorded to Drs. T. J. Henneberry and N. C. Toscano, Annual Review Program Co-Chairs and their staffs, to the Silverleaf Whitefly Technical Working Group, to the National, State and local Coordinators, and to the Program Chairs for their substantial efforts in this process. Particular appreciation is accorded to T. Perring, N. Toscano and C. Giorgio and their staffs for local arrangements.

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Executive Summary

The silverleaf whitefly has caused extensive damage to cultivated crops in Arizona, California, Texas and Florida as well as many other states under nursery and greenhouse conditions. A coordinated, cooperative research and action program involving federal and state agencies, state agricultural experiment stations and commodities industries has effectively provided open lines of communication and strong research linkages, information exchange and optimum utilization of resources to provide solutions to the problem. The program has also resulted in the active participation and attendance of representatives from ten foreign countries. Six high-priority research areas have been identified and annual research progress reviews conducted to exchange information, reassess priorities and identify new areas of research needed.

Epidemic whitefly outbreaks occurred in Arizona and California beginning in the early 1980's, and subsequently in Florida in 1987 and Texas in 1988. The sweetpotato whitefly (SPW), *Bemisia tabaci* (Gennadius), has been an economic pest in the United States and worldwide for many years. However, the expanded host range involved in the current whitefly outbreaks, biological, genetic and vector differences and the occurrence of unique adverse plant physiological disorders occurring in some cultivated crops led several authors to propose the occurrence of a new SPW biotype (Strain B) which was later described as a new species *Bemisia argentifolii* Bellows and Perring, the silverleaf whitefly (SLW).

Economic losses occur from direct SLW feeding damage that reduce crop yield, honeydew contamination and associated fungi and SLW vectored viruses. For example, honeydew contaminated lint (sticky cotton) has become a limiting factor in some cotton-producing countries and a highly important quality consideration in the textile industry. Sticky cotton problems have increased dramatically because of the extremely high SLW populations.

The SPW on a worldwide basis is considered the most important virus vector of the whitefly species. The similarities and differences between the SPW and the newly described SLW as virus vectors have not been investigated intensively. However, the occurrence of Lettuce Infectious Yellows virus vectored by SPW has been dramatically reduced in Southern California melon and lettuce fields since the SLW has become the predominant species occurring in the area. The virus-inducing cotton leaf crumple disease is transmitted by SPW in the United States. Although cotton yield reductions occur, cotton leaf crumple has not been considered a serious threat to cotton production in the Southwest because of late-season, low incidence occurrence. The potential for cotton leaf crumple to become a significant factor in cotton production systems with SLW populations is unknown. The situation needs careful monitoring. Since the introduction of SLW into Florida, whitefly transmitted gemini viruses have been identified infecting tomatoes, cabbage and beets. Prior to the occurrence of SLW, many weed species in Florida were observed with symptoms characteristic of gemini viruses suggesting that the expanded host range of SLW compared to SPW may be a threat to increasing virus-induced plant diseases. Additionally, several new physiological plant disorders have occurred and appear associated with SLW, but remain uncharacterized.

The transition from SPW to SLW dominated agricultural systems in Arizona, California, Texas and Florida is not, at present, clearly defined but it appears to have occurred during the mid to late 1980's. Current economic losses from SLW infestations in the agricultural community include losses to cotton and a wide range of ornamental and vegetable crops. Expanding SLW infestations in 1992, 1993 and 1994 on cotton and numerous other crops in the San Joaquin Valley, California, infestations in Georgia, South Carolina and other states on cultivated crops, as well as increasing incidence of vectored plant diseases, suggest that the full extent of the problem may not yet be realized.

Annual Review Objectives

The third annual research progress review of the 5-Year National Silverleaf Whitefly Research and Action Plan was conducted 28-31 January 1995 in San Diego, CA. The six high-priority research areas and research approaches provide a focus for efforts to achieve the goals and objectives of the plan within a 5-year timeframe. The plan remains open-ended and provides for modification, termination, or reduced research effort in areas of poor progress and estimated potential for successfully providing useful information for silverleaf whitefly control and management. It also provides for identification of new areas of research not covered in the plan and/or redirection of existing or establishment of new research priorities. The objectives of the annual review process will be to provide: (1) presentations of research progress in each research priority area of the plan, (2) provisions for intense scrutiny of research programs in relation to goals and objectives of the research approaches, (3) opportunities to discuss the significance of the research progress in relation to impact on development of technology to solve the silverleaf whitefly problem and finally, (4) recommendations regarding appropriateness of existing priorities and need for adjustments in the plan.

Research Progress on the Silverleaf Whitefly 5-Year National Research and Action Plan

Annual progress reviews were held in Tempe, AZ on January 18-21, 1993, and Orlando, FL, January 24-27, 1994 (USDA 1993, 1994). Each year substantial progress was reported in all of the national plan's priority areas (Table 1). Abstracts (117 in 1993, and 146 in 1994) of ongoing research show that extensive national effort is being expended to provide immediate and short-term relief from losses as a result of the SLW. Importantly, the progress in developing basic and fundamental information on natural enemies, SLW biology, virus-vector relationships, host-plant interactions and population dynamics provides a firm base for the development of efficient long-term and acceptable strategies to manage SLW populations.

A complete, effective management system for SLW is a goal for the future and, at present, is in the early formative stages. However, extensive ecological, biological and fundamental research on the SLW and its natural enemies is revealing many potential components for incorporation into an ecologically-based management system. Some crop management and community-oriented farm practices are being implemented in an effort to provide overall whitefly population reduction. The extensive cultivated crop host range, wild weed hosts and urban ornamental and weed hosts combine to provide a year-long spatial and temporal continuum of host biomass that provide food, shelter and reproductive requirements throughout the year. The resulting complex interrelationships of types of cultivated crops, crop growing sequences and urban community hosts have an impact on and are of concern to the entire farm community in whitefly population development.

Areawide community-involved approaches to SLW management have the best possible chance of success. For example, the cotton grower in a farming community must give careful consideration to the status of winter-spring cultivated crop sequences in proximity to prospective cotton planting locations. Although low SLW populations occur on vegetable crops such as broccoli, lettuce and cole crops during October through February and March, populations developing in early spring melons increase dramatically in April to May and high numbers move to cotton. Thus, early harvest and melon crop residue destruction and plowdown is an essential SLW management component for the cotton grower. An early and uniform cotton planting date scheduling may escape high, early-season infestation levels. Planting upwind of infested or potentially infested cultivated crop hosts is a further precaution to managing early-season infestations. Smoothleaf cottons support lower SLW population levels than hairy-leaf cottons. Also, short-season cotton types for early harvest and crop destruction are effective measures to reduce overall population densities in areawide farming community programs.

Water and fertilizer management are important factors in SLW management. Although the mechanisms involved in the complex interaction of the host plant condition and SLW population dynamics are largely unknown, SLW increase dramatically when cotton plants become stressed. Thus, frequent and adequate irrigation during the season delays the occurrence of high population densities. These effects have been studied primarily in cotton production, and information is much needed on other crop production systems.

Several insecticides alone or in combination have been found to provide adequate SLW control on major cultivated crops. Particular attention must be given to good coverage, particularly to underleaf surfaces. Insecticide resistance management is a particularly important factor in SLW control. It is important to avoid using materials in the same chemical class for extended periods. Frequent population monitoring of the adult and immature populations on leaves is critical to assess effectiveness of control strategies. Definitive economic threshold values have not been established but high population levels cause severe defoliation and reduced yield as well as sticky cotton and significant losses in vegetable, ornamental and nursery crops. Community action programs involving research, extension, industry, growers and the urban community are essential to provide the framework for SLW population management systems.

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Table 1. Numbers of Research Reports[a] at the 1993 and 1994 Silverleaf Whitefly Annual Progress Reviews of the USDA 5-Year National Research and Action Plan.

Agency[c]/State	Research Priorities[b] A	B	C	D	E	F	Total
1993 Review, Tempe, AZ							
APHIS	0	1	0	1	0	1	3
ARS	7	11	19	13	7	0	57
AZ	2	3	4	1	0	1	11
CA	3	3	4	2	3	0	15
FL	2	3	2	2	2	1	12
GA	0	0	4	0	2	0	6
NY	1	0	1	1	0	0	2
OH	0	0	1	1	0	0	2
TX	1	1	2	0	2	2	8
TOTAL 1993	16	22	37	21	16	5	117
1994 Review, Orlando, FL							
ADA	0	0	1	0	0	0	1
APHIS	0	0	0	3	0	0	3
ARS	7	14	13	10	5	1	50
AZ	7	4	5	4	2	3	25
CA	4	5	13	6	3	1	32
CDFA	0	0	0	2	0	0	2
FL	0	3	5	3	2	2	15
GA	0	0	1	0	0	0	1
HI	1	1	0	0	0	0	2
SC	0	1	0	0	0	0	1
TX	1	0	1	2	1	0	5
WI	0	2	0	0	0	0	2
OTHERS	1	0	4	2	0	0	7
TOTAL 1994	21	30	43	32	13	7	146

(a) From USDA 1993, 1994.

(b) A = Ecology, population dynamics and dispersal; B = Fundamental research, behavior, biochemistry, biotypes, morphology, physiology, systematics, virus diseases and vector interactions; C = Chemical control, biorationals and pesticide application technology; D = Biocontrol; E = Crop management systems and host plant resistance; F = Integrated techniques, approaches and philosophies; others = Dominican Republic, Valent, Miles, AirTech and Fermone Corps.

(c) APHIS = USDA, Animal and Plant Health Inspection Service; ARS = USDA, Agricultural Research Service; ADA = Arizona Department of Agriculture; CDFA = California Department of Food and Agriculture.

Reports of Research Progress
Section A. Ecology, Population Dynamics, and Dispersal
Co-Chairs: Marshall Johnson and Larry Godfrey

Investigator's Name(s): James R. Brazzle[1], Kevin M. Heinz[2], Michael P. Parrella[1], and Anne F. Wrona[3].

Affiliations & Locations: Department of Entomology, University of California, Davis, CA 95616[1]; Biological Control Laboratory, Department of Entomology, Texas A&M University, College Station, TX 77843[2]; University of California, Cooperative Extension, Holtville, CA 92250[3].

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: August 1993 - December 1994.

Pattern Analysis of *Bemisia argentifolii* Infesting Imperial Valley Cotton

The outbreak of silverleaf whitefly in the Imperial Valley has often been attributed not only to the biological changes of the pest itself, but also changed agronomic practices, which provide a continuum of host crops and the disruptive influence of continuous insecticide use. To better understand the influence of these agronomic and management factors a study was conducted in the summers of 1993 and 1994. This study describes the patterns of *B. argentifolii* infesting cotton, and how these patterns are affected by various agronomic and management factors.

Densities of immature whiteflies were monitored, via leaf samples, in cotton fields scattered throughout the Imperial Valley, CA. In 1993, 56 cotton fields were sampled from August 3rd to August 6th. In 1994, a more extensive study was undertaken in which 30 cotton fields were sampled four times from late May continuing through August. The densities of immature whiteflies were then analyzed in conjunction with eight measures of agronomic and management factors. The factors consist of the following eight variables: (1) the number of insecticide applications, (2) the number of organophosphate applications, (3) the number of pyrethroid applications, (4) the number of active ingredients applied, (5) the distance to the nearest spring melon field, (6) the acreage of spring melon fields within a 2.5 km radius, "the effective migration distance," of each cotton field, (7) the planting date of each cotton field and (8) the size in acres of each cotton field. Attempts were made to include natural enemies as another variable, however only variables with values consistently greater than zero were included. These data were derived from pesticide use records, individual growers and maps developed with the aid of Arc/Info, Geographic Information System.

Through principal components and multiple regression analyses relationships between the various agronomic and management factors and the densities of immature whiteflies were derived. The influence of insecticide use reveals a negative correlation in 1993 that holds true throughout the season in 1994. This correlation is intuitive, in that, as the number of insecticide applications increase, the density of immature whiteflies decreases. With the influence of spring melon fields, we observe a negative correlation for distance and a positive correlation for acreage in 1993. These correlations are interpreted as follows: as the distance from each cotton field to the nearest spring melon field increases the density of immature whiteflies decreases, and as the acreage of spring melon fields present within a 2.5 km radius of each cotton field increases the density of immature whiteflies increases. In 1994 these correlations hold true early in the season with opposing correlations observed later in the season. These correlations point to the influence of spring melon fields as a source of whiteflies, particularly early in the cotton growing season. Examining the influence of planting date a positive correlation exists in 1993 and 1994. In other words, the later in the season cotton is planted the greater the whitefly pressure. This positive correlation holds true both in 1993 and throughout the season in 1994 suggesting the age and corresponding health of the cotton plant may affect whitefly residents. As for the influence of cotton field size a negative correlation exists for 1993 and 1994. Therefore, as the size of a cotton field increases the density of immature whiteflies decreases.

As we continue to gather and analysis this large database we hope to produce clearer patterns and provide some interesting information on the influence of other agronomic practices, as well (e.g. the influence of alfalfa, irrigation practices, etc.).

Investigator's Name(s): Al G. Brower and David N. Byrne.

Affiliations & Locations: University of Arizona, Department of Entomology.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1993 - 1994.

Population Dynamics of Whitefly Predators Occurring Naturally in Cotton

For the last two summers, we have been examining the populations of possible whitefly predators occurring naturally in cotton. During the summer of 1993, *Geocoris pallens*, *G. punctipes*, *Orius tristicolor*, *Chrysoperla carnea*, and spiders of the genus *Misumenops* were the predators most commonly found in our unsprayed field. *Misumenops* spp. appeared most consistently, with population levels varying little over the season. Populations of *G. pallens* and *G. punctipes* peaked at the beginning and end of the season respectively. *O. tristicolor* and *C. carnea* numbers also were highest near the end of the season.

For the summer of 1994, we used three unsprayed cotton fields to again examine predator populations, as well as differences between fields. *Geocoris* populations again showed peaks at the beginning and end of the seasons (*G. pallens* and *G. punctipes*, respectively), but at much lower numbers than the summer of 1993. Spiders were found in extremely low numbers and showed no trends. *O. tristicolor* and *C. carnea* showed a late season peak similar to the 1993 season, but with lower numbers. Only *Orius* populations differed significantly between fields.

Regression analysis on 1993 data show that *O. tristicolor* and *C. carnea* populations correlated ($r^2 = 0.90$, $P < 0.001$) with whitefly populations and with other possible prey items (in total; $r^2 = 0.75$, $P < 0.001$), but not significantly with atmospheric conditions, plant characteristics (height, number of leaves) prey diversity or other predator populations. Other predator populations did not correlate significantly with any tested factor. Similarly, predator populations for 1994 did not correlate significantly with any tested factor so far (regression with whiteflies has not yet been completed).

It is already known that these predators are able to consume large numbers of whiteflies in controlled laboratory conditions. Although field studies point out which natural predators are most promising, they also show that predator numbers are generally too low to control whitefly populations. Further laboratory studies are testing the hypothesis that whiteflies do not offer a great enough nutritional reward (qualitatively or quantitatively) to sustain healthy predator populations. Whiteflies either have a high handling time to food mass ratio or are lacking in some nutrient(s) required by most predators.

Investigator's Name(s): David N. Byrne[1], Robin J. Rathman[1], Tomas V. Orum[2], and John C. Palumbo[1].

Affiliations & Locations: Departments of Entomology[1] and Plant Pathology[2], University of Arizona, Tucson, AZ, 85721.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: January 1993 - January 1994.

Localized Migration by Sweet Potato Whiteflies

Earlier experiments have determined that laboratory populations of *Bemisia tabaci* consist of both migratory and trivial flying morphs. The behavior of these forms as part of the process of short-range or localized migration needed to be examined under field conditions. Populations were marked in a field of cantaloupes, *Cucumis melo* L. using fluorescent dust during three consecutive growing seasons. During the first growing season passive traps, used to collect living whiteflies, were placed along 16 transacts radiating out from the field to a distance of 1.0 km. Wind out of the northeast consistently carried migrating whiteflies to traps along placed along transacts in the southwestern quadrant because cold air drainages dictate wind direction during early morning hours in the desert Southwest. For this reason, during the second and third seasons traps were laid out in a rectangular grid extending to as much as 2.7 km in 1993 and as much as 4.8 km to the southwest of the marked field. Geostatistical techniques were used to describe patterns of dispersal. If dispersal was solely wind directed, patterns could be described using a diffusion model. Variograms and indicator maps show, however, that the distribution on all days was patchy. Traps in the immediate vicinity of the marked field caught more whiteflies than the daily median. Large numbers were also collected from around the periphery of the grid. Whiteflies were virtually absent in the center. These patterns confirm behavior observed in the laboratory, i.e., a portion of the population are trivial fliers that do not engage in migration, and a portion initially ignore vegetative cues and fly for a period of time before landing. Although whiteflies were caught in the most distant traps (4.8Km away), few were found there indicating that under our conditions this distance may define the limits of localized migration.

Investigator's Name(s): Steve Castle and Tom Henneberry.

Affiliations & Locations: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: February - October, 1994.

Seasonal Sex Ratio Dynamics of Whiteflies in Imperial Valley, CA

The relative number of male and female whiteflies can be an important factor in the growth trajectory of a population. This may be true especially during early season if females predominate while populations are small and highly localized on a limited resource base. With the expansion of the resource base and improvement in environmental conditions during spring, individual fitnesses of reproductive females may be maximized by producing a greater proportion of female progeny. There are a number of potential mechanisms in haplodiploid insects such as whiteflies that can affect population sex ratios. Although there has been little or no study on mechanisms of sex ratio determination in whiteflies, a few reports from the Near and Middle East have indicated that field sex ratios can vary between male-biased to female-biased, with shifts from one to the other occurring sometimes within a crop season.

We began counting the number of males and females from both suction and emergence samples collected from various host plants in the Imperial Valley beginning in late February, 1994. A total of 11,891 adults were collected in suction samples during the February-March period, of which 9309 (78%) were female. An additional 7643 adults were collected from emergence chambers in which leaves laden with whitefly pupae had been placed. Of these, 5646 (74%) were female.

Monitoring adult whitefly sex ratios continued through spring in six commercial cantaloupe fields and through summer in eight commercial cotton fields. Suction samples were collected from the four corners of each field throughout the monitoring period, alternating weekly with leaf samples collected from the same fields to determine the sex ratio of emerging adults. Suction samples collected in late March and April were invariably strongly female biased, often consisting of 80% or greater females. A total of 125,000 adult whiteflies were collected through the first week of June from the commercial cantaloupe fields, comprised of 86,174 (69%) females and 38,826 (31%) males. A total of 40,761 whiteflies were collected from the cantaloupe leaf emergence samples, of which 59% were female. Whiteflies were collected by suction on eight dates during summer in cotton. Six of the eight total samples (from 8 cotton fields) consisted of 60% females or greater, with two of the eight between 55 and 59% female. Total emergence samples from all fields combined on three different collection dates varied between 60 and 64% female.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1994.

A Computer-Assisted Recognition System for Whiteflies

A computer-assisted recognition system designed to assist an operator in classifying and counting whiteflies is currently being developed. The complete system runs in a windows environment on a personal computer with a VGA monitor supporting 24-bit color. Images are input to the system using tagged image file format (TIFF) files. The system segments the files into individual objects and attempts to identify each one automatically. If unable to identify the objects, the system will present the image to allow the operator to identify the object. The system is trained by loading TIFF images of multiple objects of a known sample. The data from the samples are used to generate a statistical data base which is used as a reference for future identification. This system is currently being designed to identify whiteflies on cards in order to maximize counting efficiency.

Investigator's Name(s): L.D. Godfrey[1], P.B. Goodell[2], C.G. Summers[3], W.J. Bentley[4], T. Prather[2], R. Coviello[5], T.M. Perring[6], and T.S. Bellows[6].

Affiliations & Locations: Department of Entomology, University of California, Davis, CA[1]; Statewide Integrated Pest Management Project, University of California-Davis, Kearney Agricultural Center[2]; Department of Entomology, University of California-Davis, Kearney Agricultural Center[3]; Cooperative Extension, University of California, Bakersfield, CA[4]; Cooperative Extension, University of California, Fresno, CA[5]; Department of Entomology, University of California, Riverside, CA[6].

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1 January 1994 - 31 December 1994.

Seasonal Development of Silverleaf Whitefly Populations on Crop and Weed Hosts in the San Joaquin Valley

Populations of silverleaf whitefly (SWF) were sampled on crop and weed hosts within twelve sample sites (36 sq. mi. each) in Kern, Kings, Tulare, Fresno, and Merced counties in the San Joaquin Valley (SJV) of California. Sampling in these areas began on 1 May 1993 and has continued to the present. Results from 1994 will be reported herein. Within each sample site, three locations of all potential SWF host plants, crops, weeds, and a limited number of ornamentals, were sampled every 2 weeks; all SWF nymphs were counted for 10 minutes during a visual examination of foliage.

SWF were first detected on 3 May 1994 on honeydew melons at a site southeast of Bakersfield (Kern county). Populations at this site increased from 25 nymphs (3 May) to 7500 nymphs per 10-minute search (27 July). Within this same area, SWF were first found in cotton on 29 June and populations increased to ~1100 per 10-minute search on 21 September. SWF populations in this area occurred about 3 weeks earlier in 1994 than in 1993 and reached higher levels in 1994 than 1993. In summary, SWF were found in all 12 of our sample sites. The date of first occurrence in cotton ranged from 17 May to 11 Sept. and generally was later in the central SJV sites, i.e., Fresno, Kings counties, than the southern sites, i.e., Kern county. The greatest change in SWF populations from 1993 to 1994 was at the sample site southwest of Bakersfield. Within this area, populations in cotton peaked at ~50 per 10 minute search in 1993 whereas levels reached 500 per 10-minute search in 1994. As an example from the sample site southeast of Bakersfield, crop sequences for SWF populations were melons in the spring, followed mainly by cotton, sweet potatoes, and beans during the summer, and potatoes, carrots, tomatoes, cole crops, and alfalfa beginning in mid-late September. SWF densities varied greatly on weed host plants, but were generally found on weeds in the late summer to winter period. More than 60 weed species in more than 20 families were identified as hosts for SWF. SWF overwintered on weeds, cole crops, citrus, and ornamentals, reaching nearly non-detectable levels by the end of the winter.

Finally, three transects of yellow sticky traps (3 x 3 inches) were placed east to west across the southern, south-central, and central SJV. First occurrence and peak occurrence of SWF adults were 7 July and 16 Sept. (southern SJV transect), 22 July and 1 Oct. (south-central SJV transect) and 28 July and 20 Oct. (central SJV transect). Populations were generally highest along the southern transect and on the eastern side of the SJV for the other two transects. Populations reached nearly 2000 SWF adults per trap per 24 hour period on some traps.

Investigator's Name(s): T.J. Henneberry[1], W. Bentley[2], C.C. Chu[1], P. Ellsworth[3], P. Goodell[2], R.L. Nichols[4], S.E. Naranjo[1], D.G. Riley[5], N. Toscano[6], and T. Watson[3].

Affiliations & Locations: USDA-ARS, Phoenix, AZ[1]; University of California at Kearney[2]; University of Arizona, Tucson, AZ[3]; Cotton Incorporated, Raleigh, NC[4]; Texas A&M University, College Station, TX[5]; University of California, Riverside, CA[6].

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: February 1 - November 1, 1994.

Progress in Developing Adult Action Thresholds for Chemical Control of Silverleaf Whitefly (SLW)

In the last several growing seasons, uncontrolled silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, populations have reached economic infestation levels in commercial cotton fields in California, Arizona and Texas. Cotton lint yields have been reduced and in some cases honeydew contamination of lint has occurred resulting in substantial discounts. A cooperative study involving Cotton Incorporated, the Universities of Arizona and California, Riverside, Texas A&M University and the USDA-ARS, Western Cotton Research Laboratory has been initiated to determine the relationship between SLW populations, cotton yield and honeydew lint contamination. In 1994, replicated field trials were conducted at Brawley and Bakersfield, California, and Maricopa and Yuma, Arizona, and Weslaco, Texas. SLW adults were sampled at weekly intervals using the leaf turn method. Immature forms were counted on disks from leaves picked from the 5th node from the mainstem terminal. Fenpropathrin + acephate combination sprays were made when whiteflies exceeded 2.5, 5.0, 10.0 and 20.0 SLW adults/leaf turn throughout the season. Controls were untreated. Cotton lint yields were determined in all plots.

Whitefly populations were lowest at Weslaco followed by Bakersfield, Yuma, Maricopa and Brawley, respectively. Seasonal average numbers of adults, eggs and nymphs were not significantly different among any level of treatments or the untreated control at Weslaco. At Bakersfield and Yuma, seasonal average numbers of nymphs and adults were significantly lower in plots where treatments were made at 2.5, 5.0 and 10 adults per leaf than in untreated plots. Seasonal average numbers of all life stages in treated plots at Brawley and Maricopa were significantly lower than in the untreated controls, however, there were no differences between plots treated at 2.5, 5.0 or 10 adults per leaf. Cotton lint yields were not significantly different among any treatments at Weslaco, Bakersfield or Yuma. However, at Maricopa, yields of treated plots were higher than those not treated, and at Brawley, plots treated at 2.5, 5.0 or 10 adults per leaf had higher yields than untreated plots or those treated at 20 adults per leaf.

Investigator's Name(s): T.J. Henneberry[1], D.H. Hendrix[1], H.H. Perkins[2], S.E. Naranjo[1], H.M. Flint[1], D.H. Akey[1], L. Forlow Jech[1], and R.A. Burke[1].

Affiliations & Locations: USDA, ARS, Western Cotton Research Laboratory, Phoenix, AZ[1]; USDA, ARS, SAA, Clemson, SC[2].

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: January 1994 - December 1994.

Bemisia argentifolii Populations, Sticky Cotton, and Cotton Yields

Bemisia argentifolii Bellows & Perring adults in black pan samples were highly correlated to numbers of eggs and nymphs and nymphs highly correlated to eggs from whole leaf samples in 1991 and from 3.88 cm^2 leaf discs in 1993. In 1991, minicard sticky cotton ratings (0.0 to 0.4) for lint were low but positively correlated to *B. argentifolii* adults and adults plus nymphs, but not nymphs alone. In 1993, densities of *B. argentifolii* and minicard sticky cotton ratings were higher in untreated plots as compared to plots treated with 3 or 6 insecticide applications during the season. Trehalulose, melezitose, fructose and glucose were positively correlated to minicard sticky cotton ratings. *B. argentifolii* adults, nymphs, and adults plus nymphs were also highly correlated to the insect produced sugars, trehalulose and melezitose. *B. argentifolii* populations were also significantly and negatively correlated to cotton lint yields in 1993, but not in 1991.

Investigator's Name(s): Rufus Isaacs and David N. Byrne.

Affiliations & Locations: Department of Entomology, University of Arizona, Tucson, AZ.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: October 1994 - January 1994.

Migratory Behavior of the Sweet Potato Whitefly

Many facets of the migratory behavior of *Bemisia tabaci* (Gennadius) are not fully understood, and many have yet to be investigated in detail. This research tackles these gaps in our knowledge by using morphological, behavioral and ecological techniques to answer questions about the behavior of this insect during its movement between patches.

It is likely that there is developmental plasticity in terms of whether adult whiteflies make migratory or trivial flights and we are investigating the biotic and abiotic factors affecting the production of these two morphs. Morph determination has been studied in detail for aphids and to some extent for whiteflies, and this work will provide an insight into the extent to which whitefly-host plant interactions are governed by the same mechanisms as for aphids. The data generated on whitefly biology will be essential for the development of a predictive model which collaborators on our project are compiling to enable forecasting of migration by this insect.

A study in progress has been set up to examine the effects of plant water stress during whitefly development on cantaloupe melons (*Cucumis melo* L.) on the flight behavior parameters of *B. tabaci*. Adults that develop on melon plants under three different watering regimes in a greenhouse will be tested in a vertical flight chamber for the proportion of insects making persistent flights towards the white overhead light (migrants) and for the proportion exhibiting targeted flights towards a green light cue (trivial flyers). Rates of climb, flight duration and horizontal displacement will also be measured. Effects of host quality on *B. tabaci* flight behavior will also be investigated by confining adults on plant species of different suitability and measuring the flight behavior of their progeny, as above.

Field studies will be carried out at Yuma Agricultural Center and at the University of Arizona Farm in Tucson during 1995 to further investigate the effects of crop water stress and host quality on the flight parameters of *B. tabaci*.

Other aspects of flight behavior, including responses to color and distribution of migratory and trivial flyers will be examined in controlled laboratory conditions and in field trials.

Investigator's Name(s): S.E. Naranjo[1], P.C. Ellsworth[2] and J.W. Diehl[2].

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: May 1 - November 1, 1994.

Validation and Analysis of Sampling Plans for *Bemisia tabaci* in Cotton

Reliable and cost-effective sampling methods are important to the study of the biology and ecology of *Bemisia tabaci* Genn.(also referred to as *B. argentifolii* Bellows & Perring) and are central to the development of monitoring programs for pest management. We have recently developed several numerical and binomial sampling plans for adult *B. tabaci* in cotton. These plans enable the precise estimation of population density and also allow us to classify populations for pest management decision-making. Validation and evaluation of sample plan performance are critical, but often overlooked, phases in the development and implementation of robust sampling plans.

As part of a community-wide pest management program, we implemented and tested our sampling plans within a large cotton-production area in central Arizona. We examined the adequacy of our models in describing the spatial distribution of adult *B. tabaci* populations and also evaluated their performance in pest management decision-making relative to established action thresholds. In 1994 samples were taken weekly in 190 commercial cotton fields from mid-May through mid-August. In approximately half of these fields adults were counted on 25 leaves from each of 4 quadrants for a total of 100 samples per field. These sample data were used in our analyses. We use an approach in which actual field data is resampled numerous times on a computer. Thus, the data defines the spatial distribution and resampling permits evaluation of the average performance of the sample plan as well as the variation associated with this average. We examined precision, number of samples needed, and error probabilities in decision-making for *1)* fixed-precision sequential sampling, *2)* sequential binomial sampling and *3)* fixed-sample-size binomial sampling models.

The mean-variance model developed from 1993 samples generally under-and over-predicts variances at densities < or >1, respectively. As a consequence, the fixed-precision sequential model requires too few or too many samples at densities < or >1, respectively. An empirical binomial model also developed from samples in 1993 generally under- and over-predicts mean densities < or >2, respectively. Thus, the decision to suppress is taken more often at densities slightly below the action threshold, but few errors are made at densities above the threshold. Error probability curves were very similar between sequential and fixed-sample-size models. On average, the sequential binomial decision model required fewer than 25 samples regardless of density; however there was high variability in required sample number, particularly at densities near the action threshold. The fixed-sample-size decision model requires more samples but performs well and permits better coverage of the field.

Investigator's Name(s): J.C. Palumbo and D.G. Riley.

Affiliations & Locations: University of Arizona, Yuma Valley Agricultural Center, Yuma, AZ; and Texas Agricultural Experiment Station, Weslaco, TX.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1992 – 1994.

Interaction of Silverleaf Whitefly With Melon Crop Quality

A range of population levels of silverleaf whitefly, *Bemisia argentifolii* (previously b–strain sweetpotato whitefly, *Bemisia tabaci* Gennadius) was evaluated in three field experiments allowing measurement of the effect of whitefly numbers on melon quality and yield. An increase in total numbers of immature whitefly was associated with significant declines in harvested melon weight, a decline in number of boxes harvested, a decrease in fruit size, a decrease in percent sugars, an increase in sooty mold and, in one experiment, an increase in the incidence of downy mildew. Regression analysis of individual whitefly life stages with yield parameters indicated that at low population density (Texas), the number of large whitefly nymphs was a more precise parameter for estimating effects on various melon yield quality measurements than adults. At high population density (Arizona), adult number was a more precise parameter. Also, higher R^2 values were obtained with increased range of whitefly population densities. Adults were sampled at the third leaf node in both locations. Estimates of the mean adult silverleaf whitefly density resulting in 5% and 15% dollar–yield loss were 3 and 10 adults per leaf under high (AZ) whitefly population density. Nymph samples were taken at a fixed position, the six leaf node from the apical meristem in Texas, and at varying nodes from the base of the plant in AZ. Estimates of the mean total nymph density resulting in 5% and 15% dollar–yield loss under low (TX) and High (AZ) whitefly population densities were 0.1 and 0.4 (TX) and 0.5 and 2 (AZ) nymphs per cm^2 of leaf area, respectively.

Investigator's Name(s): J.C. Palumbo and N.C. Toscano.

Affiliations & Locations: University of Arizona, Yuma Valley Agricultural Center, Yuma, AZ; and Department of Entomology, University of California, Riverside, CA.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1993 – 1994.

Impact of Silverleaf Whitefly Populations on Yield and Quality of Alfalfa

The experiment was conducted during the late spring and summer of 1994 on a first year stand of alfalfa. Plots were arranged in a randomized complete block design with two treatments and six replicates. Plot sizes were 0.2 ha with a bare soil border (0.05 ha) between each plot. Treatments consisted of an untreated control and weekly foliar applications of a mixture of fenpropathrin (0.2 lbs ai/acre) and acephate (0.5 ai/acre). SLW egg and nymph population densities were estimated weekly by random removal of 10 alfalfa stems from each plot. All stages of SLW were counted in the laboratory on trifoliates selected from the upper and lower positions of each stem. Forage yields were estimated at each harvest by clipping the stems within three 1.0 m^2 sections within each plot. All leaves and stems from each 1–m^2 section were initially weighed and then placed in a forced–draft oven at 70°C for 48 hr. Forage quality was measured by estimating sooty mold contamination on trifoliates and stems.

In 1994, we were able to maintain significant differences in SLW densities between the treated and untreated plots. Consequently, significant reductions in forage yield and dry matter production occurred during the August cutting associated with heavy immature SLW densities (Table 1). Although yield effects were not as significant ($P = 0.10$) during the Sep cutting, reductions were observed. Forage quality was low for untreated plots only during the September cutting, as 29% foliage in untreated plots was at harvest. Sooty mold and honeydew accumulations may have increased forage and dry weights in untreated plots. Preliminary results of protein analysis show no reduction in crude protein associated with heavy SLW densities.

Investigator's Name(s): John Palumbo[1], Wee Yee[2] and Nick Toscano[2].

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1993 - 1994.

Development of Seasonal Action Thresholds for Chemical Control of Silverleaf Whitefly on Alfalfa

The experiment was conducted during the late spring and summer of 1994 on a first year stand of alfalfa. Plots were arranged in a randomized complete block design with two treatments and six replicates. Plot sizes were 0.2 ha with a bare soil border (0.5 ha) between each plot. Treatments consisted of an untreated control and weekly foliar applications of a mixture of fenpropathrin (0.2 lbs ai/acre) and acephate (0.5 ai/acre). Silverleaf whitefly (SLW) egg and nymph population densities were estimated weekly by random removal of 10 alfalfa stems from each plot. All stages of SLW were counted in the laboratory on trifoliates selected from the upper and lower positions of each stem. Forage yields were estimated at each harvest by clipping the stems within three 1.0 m^2 sections within each plot. All leaves and stems from each 1 m^2 section were initially weighed and then placed in a forced-draft oven at 70°C for 48 hr. Forage quality was measured by estimating sooty mold contamination on trifoliates and stems.

We were able to maintain significant differences in SLW densities between the treated and untreated plots. Consequently, significant reductions in forage yield and dry matter production occurred during the August cutting associated with heavy immature SLW densities. Although yield effects were not as significant ($P = 0.10$) during the September cutting, reductions were observed. Forage quality was low for untreated plots only during the September cutting, as 29% foliage in untreated plots was at harvest. Sooty mold and honeydew accumulations may have increased forage and dry weights in untreated plots. Preliminary results of protein analysis show no reduction in crude protein associated with heavy SLW densities.

Investigator's Name(s): D.G. Riley and J.C. Palumbo.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1992 – 1994.

Action Thresholds for Silverleaf Whitefly in Cantaloupe

A range of action thresholds for control of silverleaf whitefly, *Bemisia argentifolii* (previously b–strain sweetpotato whitefly, *Bemisia tabaci* Gennadius) was evaluated in two field experiments one in Texas with low populations and one in Arizona with high population density of *B. argentifolii*. Both adult–based and nymph–based action thresholds were estimated and tested. In Texas, action thresholds for whitefly large nymphs, based on seasonal nymph averages that could result in 5%, 10%, and 20% dollar–yield losses, of 0.5, 1, and 2 large nymphs per 7.6 cm^2 of leaf area, respectively, were tested. Samples for nymphs were taken between the 6th and 9th leaf node from the apical meristem. Also, action thresholds for whitefly adults based on seasonal whitefly averages that resulted in 5%, 15%, and 30% dollar yield losses of 1, 3, and 6 adults per leaf, respectively, were tested. Samples for adults were taken at the 3rd leaf node. In AZ, action thresholds for whitefly adults, based on seasonal whitefly averages that could result in 5% and 15% dollar losses, of 3 and 10 adults per leaf, respectively, were tested. All thresholds were compared to weekly insecticide treatments and an untreated check. The resulting best threshold treatment in TX was 0.5 large nymphs per 7.6 cm^2 leaf area which provided a 70% increase in net return over the untreated check. The best resulting threshold treatment in AZ was 3 adults per leaf which provided 170% increase in net return over the untreated check. Both of the thresholds resulted in reduced numbers of insecticide applications.

Investigator's Name(s): James H. Tsai and Kaihong Wang.

Affiliations & Locations: University of Florida, Ft. Lauderdale Research and Education Center.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1993 - 1994.

Development and Reproduction of Silverleaf Whitefly *Bemisia argentifolii* (Homoptera: Aleyrodidae) on Five Vegetable Crops

Effects of five commercially grown vegetables on the development, survivorship and reproduction of silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring were studied in the laboratory. The silverleaf whitefly reared on eggplant (*Solanum melongena* L.), tomato (*Lycopersicon esculentum* Mill.), sweet potato (*Ipomoea batatus* (L.) Lam), Cucumber (*Cucumis sativus* L.) and garden beans (*Phaseolus vulgaris* L.) had significant differences in their survivorship. The percentages of immature survived on eggplant, tomato, sweet potato, cucumber and garden beans were 88.69, 60.18, 67.58, 46.37 and 45.83%, respectively. Development time from egg to adult ranged from 17.31 d on eggplant to 20.95 d on garden beans. The average number of eggs laid per female were 223.67, 167.55, 77.50, 65.96, and 83.50 on the above respective hosts. Female adults lived an average of 24.03, 20.55, 16.56, 9.85 and 13.38 d on these hosts. The intrinsic rate of natural increase for *B. argentifolii* on eggplant was highest. Jacknife estimates of rm varied from 0.192 on eggplant to 0.12 on garden beans. The mean generation time of the population on these hosts ranged from 23.17 to 27.24 d at 25°C. Based on life-table analyses of silverleaf whitefly populations, we concluded that eggplant is the most suitable host for *B. argentifolii* and garden beans is the least suitable host.

Investigator's Name(s): Klaas H. Veenstra and David N. Byrne.

Affiliations & Locations: Department of Entomology, University of Arizona, Tucson, AZ.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: September 1993 - November 1994.

Physiological Adaptations for Dispersal in the Sweet Potato Whitefly

Previous mark-recapture experiments have shown the potential of short range dispersal (<5 km) in the sweet potato whitefly (*Bemisia tabaci* [Genn.]). In a flight chamber sweet potato whiteflies are capable of sustained flights for more than 2 hours, although only a small fraction engages in prolonged flight. Sustained flight in insects typically requires lipids as an energy source. For many insects (including moths, bark beetles and aphids) it has been shown that morphs that are capable of long distance flight have typically a higher lipid content. The sweet potato whitefly has, compared to other insect (including aphids), a high percentage of lipids (approximately 40% of dry weight). Several experiments were conducted or are in progress to examine the importance of lipids in the sweet potato whitefly for flight and dispersal capability.

In the first experiment whiteflies collected from the mark-recapture experiments were analyzed for total lipid content and compared to individuals collected from the source field. Only females were used in this analysis. Whiteflies collected away from the source field had a significantly higher lipid content (+ 27%) than individuals collected in the source field, if lipid content was corrected for weight ($P = 0.002$; $F_{1,217} = 10$). However the difference was not significant when lipid content was <u>not</u> corrected for weight ($P = 0.31$; $F_{1,218} = 1.1$). There was also no significant relationship between distance flown from the field and lipid content ($P = 0.22$; $F_{1,202} = 1.51$; corrected for weight). The regression line was:

$$\text{lipid content} = 2.87\ (\pm\ 0.10\ )\ \mu\text{gram} - 0.087\ (\pm\ 0.07)\ *\ \text{distance (in km)}$$

In another experiment whiteflies were released in groups in a vertical flight chamber. The lipid contents of individuals that ascended into the airstream were compared with individuals that did not fly. Individuals that showed a response had approximately 20% higher lipid content (corrected for body weight; $P = 0.014$; $F_{1,19} = 7.36$).

Additional experiments showed that in adult females lipid content increased significantly in the first two days after emergence, but not thereafter (in both absolute amount per individual and relative to body weight). In adult males however lipid content seemed to remain constant during their adult live. Lipid analysis of eggs showed that they could be important sinks of lipids as well. Approximately 29% of the total lipids in females is tied to developing eggs in the females caught in traps.

Current efforts are underway to quantify individual components of sweet potato whitefly lipids. We are also examining the effects of host plant quality on lipid synthesis.

Investigator's Name(s): T.F. Watson, M.A. Tellez, S.E. Johnson, S. Sivasupramaniam, and P.W. Brown.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: January 1992 - December 1994.

The Sweetpotato Whitefly, *Bemisia tabaci*, (Gennadius) in Arizona: Ecological Factors Affecting Outbreaks and Control in Cotton

The seasonal dynamics of sweetpotato whitefly (SPWF) populations have been studied for several years in Yuma County and for two years in Maricopa County, Arizona. The 1993 study provided additional information to the understanding of the seasonal dynamics of the sweetpotato whitefly.

Mild winters with little, if any, freezing temperatures are extremely important to overwintering survival since this pest has no dormant stage. Large differences in nighttime temperatures within short distances, as a result of airflow patterns, could significantly influence overwinter survival. Windflow and direction influence whitefly management, resulting in much heavier infestations downwind from a source infestation. Rainfall is detrimental to adult whitefly populations but, this benefit is of short duration. Populations bounce back from the immature populations on the plant foliage.

The proximity of a whitefly source affects infestations in other host crops. The result is usually a delay in the infestation of crops planted at greater distances from the preceding hosts.

In Arizona, several crops (and weeds) provide the overwintering hosts. Cantaloupe is a highly attractive spring host. High populations develop and subsequently move to cotton upon the senescence of the cantaloupe vines. Transfer of whiteflies from cantaloupe and watermelon to cotton was substantiated. Massive population buildup, senescent crops, disturbances such as weeding or spraying operations and plowing under of the crops resulted in the movement of whiteflies from melon to cotton. However, these studies definitely demonstrated the feasibility of controlling whiteflies in a mixed (melon/cotton) agroecosystem, provided effective chemical and cultural control practices are employed.

Large populations of SPWF exist in and around backyard plantings and commercial nurseries. The impact of these populations on the adjacent agricultural sectors is yet unknown.

This study showed the importance of host sequences, cropping patterns, crop residue destruction, and other practices, including effective chemical control on producing good cotton, even in the presence of whitefly infestations. It also indicated the importance of community-wide efforts for the most satisfactory solution to this problem.

Investigator's Name(s): L. Wendel, R. Weddle, and G. Culver.

Affiliations & Locations: USDA-APHIS, Mission, TX; Agricultural Commissioner's Office, Imperial County, CA.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1992 - 1994.

Survey of *Bemisia tabaci* on the Colorado Desert, Imperial Valley, California

This survey is being conducted to determine the practicality of using native desert sites as biological control refuges for the release of natural enemies, and to collect background information to support evaluations of any future release/refuge programs.

Two survey routes were established; one on the eastern desert and one on the west. After five months, the western route was changed to include more native plant species away from cultivation. Plant voucher specimens are collected, identified and stored in the Imperial County Agricultural Department Herbarium. The survey routes are checked weekly for changes in plants and for whitefly activity. Leaf samples are taken for parasite incubation when *Bemisia* "pupae" are present, and if there seems to be enough plant and whitefly that the sampling will not significantly alter any trend.

The local desert vegetation consists primarily of creosote bush scrub of varying densities. A few species of small trees grow in and along the washes. The west side of the valley is drier, with fewer and smaller plants, while the east side, which is more often hit with summer storms, has almost dense vegetation in some of the washes.

To date, *Bemisia* is more attracted to the seasonal plant species than to the perennial shrubs and trees. *Datura discolor* (Jimson weed) and *Dicoria canescens* (Bugseed) are summer and fall hosts (depending on rainfall) and during winter and spring, *Bemisia* has been found on *Brassica tournefortii* which comes up thickly in a wet year (it is an agricultural weed). In all, 28 plant species have hosted *Bemisia*, but most for only a short time and with low whitefly densities. Some plants which were hosts in 1992 have been found to be non-hosts in 1993 and/or 1994. Also, some of the 1992 host plants have not reappeared on the survey route, however a few new host plants have been identified. During a wet year there could be enough overlapping plant species to support a continuing population, but in a dry year such as this one, there are few seasonal plants and very little whitefly.

Records from 1992, 1993 and this year indicate that *Bemisia* showed up on the desert after populations built up in cropland. The first finds of whitefly (well away from crops) were at heavily used recreation sites. Perhaps some spread of whitefly to the desert is by vehicular traffic. There has been considerably less *Bemisia* found on the west desert than on the east (cropland and the Salton Sea lie between). This is consistent with the drier conditions. May and June have had the lowest occurrence of whitefly, and September and October the highest.

Bemisia on desert plants is preyed on by *Semidalis* sp., *Geocoris* sp., *Orius* sp., *Chrysopa* sp., *Hippodamia convergens*, and ants. Incubated *Bemisia* "pupae" have produced *Eretmocerus* sp. in highly varied percentages, and also a few *Encarsia* sp. Identification is pending.

It currently appears that the variable growth of the desert host plant species would make it difficult to establish an ongoing refuge project.

Investigator's Name(s): Wee L. Yee[1], Donald L. Hendrix[2], Nick C. Toscano[1], C.C. Chu[3], and Thomas J. Henneberry[2].

Affiliations & Locations: Department of Entomology, University of California, Riverside[1]; USDA-ARS-WCRL, Phoenix, AZ[2]; USDA-ARS-WCRL, Brawley, CA[3].

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: July - August 1994.

Continuous Honeydew Production by Silverleaf Whitefly Nymphs on Cotton

Honeydew production by silverleaf whitefly nymphs on untreated cotton was monitored over 14- or 24-hour periods during four days in Brawley, CA. Honeydew was collected by placing plastic bags by themselves or with strips of water-sensitive paper over 5-10 fifth main stem node leaves and replacing the bags and paper every 2 hours. Leaf water potentials and temperatures of 5-10 different leaves were measured concurrently to determine if these factors may be related to honeydew production. Honeydew drops on paper were counted under a dissecting microscope and honeydew collected by plastic bags were analyzed using gradient anion-exchange high performance liquid chromatography. Complete results from 16 August have been tabulated. For one 24-hour period, honeydew drops produced by nymphs feeding on a single leaf were highest between 2100-1100 h; fewest drops were produced between 1300-1900 h. For one 14-hour period, mean drop counts per 4.13 cm^2 of paper per time interval from 5 leaves ranged from 1,802 to 3,668. Higher mean numbers of drops were collected between 0500-1100 h (3,020-3,668) than 1300-1900 h (1,802-2,008). Mean mass of total sugars in honeydew was highest at 0500 h (26.64 ug/25 ul of honeydew extract) and lowest at 1900 h (13.86 ug/25 ul). The main difference between drop and mass data was that relatively high sugar masses were collected for a longer period, from 0500-1700 h. The relative honeydew sugar compositions (rankings) were constant, even though there were fluctuations in the absolute sugar compositions. Trehalulose was the predominate sugar produced throughout the day and comprised 27.6-36.1% of the total sugar mass. Melezitose was second and comprised 13.01-16.8% of the mass. Sucrose (6.8-14.0%) was next, followed by fructose (7.1-10.0%) and then glucose (1.7-4.6%). There were means of 920 first (35%), 1,254 second/third (57%), and 153 fourth (8%) instar nymphs, with a mean total of 2,328, on leaves from 16 August. Leaf water potentials were highest when temperatures were lowest ($r^2 = 0.54$; $P < 0.05$). However, honeydew production did not show consistent relationships with leaf water potentials and temperatures.

TABLE A. Summary of Research Progress for Section A – Ecology, Population Dynamics, and Dispersal, in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Yr. 3: Continue demographic studies, determine relationships between crop sequencing, preferred hosts and population dynamics.	X		Data was collected primarily in the southwestern U.S. on seasonal population dynamics. Whitefly dynamics differed with locality. This indicates a need for routine monitoring for management purposes. The biology of SLWF was determined on 5 vegetable crop hosts. Results indicated significant differences in potential whitefly reproduction and survival among the vegetable crops assessed.
A.2 Develop efficient SPW sampling plans for research and decision making purposes.	Yr. 3: Continue development and refinement of sampling plan, implement and test protocols, develop remote sensing tools to estimate regional population levels.	X		Sampling plans were developed and evaluated for cotton. These should lead to practical sampling regimes for grower use. Sampling plans are needed for the multitude of vegetable and ornamental host crops that SLWF infests. Computer assisted automatic counting system was refined and may one day eliminate the need for human counting of insect foliage samples.
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Yr. 3: Continue quantification of relationships between SPW density and yields and quality, continue formulation of economic thresholds with refined sampling protocols.	X		Much progress was achieved on correlating SLWF densities and reduced cotton lint quality. Economic thresholds on cotton are now available which permit growers to effectively time manage actions. However, no progress was reported on economic thresholds for other crops such as vegetables.
A.4 Develop and test population models to describe and predict SPW dynamics.	Yr. 3: Continue model construction, evaluate data needs, begin evaluation of model predictions of SPW development.		X	Data collected under A.5 will be used to develop models in Yr. 4.
A.5 Determine factors influencing SPW dispersal and impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems. (Combined with A.6 based on Year 1 recommendations)	Yr. 3: Determine effects of weather parameters on dispersal.	X		Dispersal abilities of SLWF adults were elucidated in desert agricultural communities and some impact of the insect's physiology on dispersal and migration potential were determined. The importance of wind movement was determined which immediately provides a management component to this problem. No progress was made on understanding the influence of dispersal on SLWF population dynamics.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Yr. 3: Continue quantification of SPW movement and determination of host sequencing and spatial patterning, integrate information into population models.			Combined with A.5.

Research Summary

Section A: Ecology, Population Dynamics and Dispersal

Compiled by: M. W. Johnson & L. D. Godfrey

General Appraisal of Progress. Thirteen abstracts were submitted which reported results that pertained to the 1994 research goals. Agricultural experiment station scientists (AES) contributed the majority of abstracts (7) received. The remaining abstracts were contributed by USDA-ARS personnel working alone (2) and in association with AES personnel (2) and AES personnel and industry (1). APHIS personnel contributed one abstract. Most of the research projects were conducted in the Southwestern U.S. (CA & AZ) with heavy emphasis on cotton. As indicated by submitted abstracts, significant progress was made on research approaches A.1 - A.3 and A.5. Fewer research accomplishments were made in 1994 relative to Section A goals than those reported for Sections B - F. The absence of progress in some areas may be correlated with the lack of resources (e.g., grant funds) available for the work and some overlap among research goals in some sections (e.g., Section F: Integrated Techniques, Approaches & Philosophies).

A.1 Define biology, phenology, and demography of Silverleaf Whitefly (SLWF) on greenhouse, field crops and wild host plants.

SLWF biology and reproduction was determined on eggplant, tomato, sweet potato, cucumber and garden beans. Immature survival was highest on eggplant and lowest on garden beans with jack knife estimations of maximum intrinsic rate of increase (rm) reflecting survivorship trends (eggplant: rm = 0.192; garden beans: rm = 0.12).

Work focused on the population dynamics of SLWF in the San Joaquin Valley, CA, on cotton, various vegetable and ornamental crops and wild plant hosts during 1994. SLWF was first detected on melons in early May near Bakersfield, Kern Co., and on cotton in late June. Further north in the central San Joaquin Valley (Fresno, Kings Counties), first occurrence of whiteflies was recorded later in the season. SLWF densities varied greatly on weed host plants, but were generally found on weeds in the late summer to winter period. More than 60 weed species (>20 families) were identified as SLWF hosts. Whiteflies overwintered on numerous host species (cole crops, ornamentals & weeds), reaching nearly non-detectable levels by winter's end.

Similar studies in the Imperial Valley, CA, conducted in 1994, showed that SLWF was more attracted to seasonal plant species than to perennial shrubs and trees. Twenty-eight plant species hosted SLWF, but most for only a short time and with low whitefly densities. Interestingly, initial finds of SLWF distant from domestic crops were found in recreational sites. Generally, SLWF was less prevalent on the west side of the desert than on the east side which may have reflected the dryer conditions on the west side. Whitefly densities were highest in May and June and lowest in September and October.

Lastly, studies in Arizona on cotton documented population dynamics of several predators (e.g., Geocoris pallens, Orius tristicolor, Chrysoperla 48%. Lastly, studies in Arizona on cotton documented population dynamics of several predators (e.g., Geocoris pallens, Orius tristicolor, Chrysoperla carnea). Geocoris populations peaked in late spring and early fall, but remained low during the summer. Orius and Chrysoperla densities peaked in late season. There were a significant correlations between whitefly densities and those of O. tristicolor and C. carnea, respectively. Year 4 goals should be pursued with respect to determining seasonal contribution of cultivated and wild host plants to SLWF population dynamics.

A.2 Develop efficient SLWF sampling plans for research and decision making purposes.

Given the numerous crop hosts infested by SLWF, research in this topic area was minimal. Studies were conducted in Arizona on numerical and binomial sampling plans on cotton. Analysis of sampling plans (fixed-precision sequential sampling; sequential binomial sampling; and fixed-sample-size binomial sampling) indicated that a fixed-sample-size decision model was the most optimal plan because it performed well (less variable estimations) and permitted better coverage of cotton fields. Some work on the development of sampling plans on cantaloupe in Arizona was also reported. Studies were also reported on sampling urban plants for whitefly in New York.

Efforts continued to prefect a computer assisted recognition system for whiteflies which could automatically detect, separate (from other insects), and count numbers of whitefly adults trapped on yellow sticky cards. The system has been designed to operate on a personal computer with a VGA monitor supporting 24-bit color. This area is in need of additional work given the necessity of easy, inexpensive, and efficient sampling regimes to implement the use of economic thresholds or action thresholds. No contributions were reported for the Year 3 goal of developing remote sensing tools to estimate regional population levels. Some related work was reported under Section F in terms of cropping patterns and integrated

management). However, given the tremendous differential in the impact of SLWF among plant species, this may not be a high priority among researchers at this time.

A.3 Develop economic thresholds for SLWF in relation to feeding damage, honeydew production and virus transmission.

Most work reported under this approach was conducted on cotton and related to contamination of cotton lint with SLWF honeydew. Efforts were made to correlate adult SLWF densities per leaf with reductions in non-contaminated cotton lint yields. At one site, it was found that when insecticide treatments were initiated at adult whitefly densities lower than 10 per leaf, greater lint yields were produced compared to those yields in untreated plots or where insecticides were initiated when adults surpassed 20 per leaf. In another study, action thresholds were based on number of whitefly nymphs per unit area of leaf surface. The recommended threshold was 0.31 nymphs/cm^2 on the 5th mainstem node leaf. Additionally, a threshold of 4.16 adults/leaf would be suitable. Work is on-going in Arizona on thresholds in cantaloupe and in California on thresholds on tomato and cole crops.

Studies showed that the sugars trehalulose, melezitose, fructose, and glucose were positively correlated with minicard sticky cotton ratings. Densities of SLWF adults and nymphs were also correlated to insect produced sugars. Lastly, it was discovered that SLWF nymphs continuously produce honeydew throughout their lifecycle. Peak honeydew production was between 2100-1100 hours, with minimum production from 1300-1900 hours. Honeydew sugar compositions were constant although absolute sugar compositions fluctuated. Trehalulose was the predominate sugar. Honeydew production did not show consistent relationships with leaf water potentials and temperatures. Investigations are necessary on other crops given the wide host crop range of this pest. Additionally, mechanisms of plant response to SLWF feeding should be determined.

A.4 Develop and test population models to describe and predict SLWF dynamics.

No abstracts were submitted under this approach. However, individuals reported that data collected in Arizona under approach A.5 would be used to generate population models. Additionally, a regional model is being developed for Imperial Valley, CA, to predict whitefly population dynamics.

A.5 Determine factors influencing SLWF dispersal and impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.

Significant progress was made in regards to determining factors influencing dispersal, but no progress was on the impact of dispersal on population dynamics. Attempts were made to discover possible correlations between lipid content in adult SLWF and their ability to fly long distances. Field experiments showed no correlation, however, vertical flight chamber tests indicated that those adults with higher lipid content (ca. 20%) ascended into the airstream compared with those individuals which did not fly.

Studies were initiated to determine possible influences of host plant water stress on the SLWF flight behavior, however, no results are available at this time. Lastly, field experiments showed that adult whitefly dispersal did not follow a diffusion pattern based solely on wind direction. Dispersal was patchy with high numbers near the source of release and some distance away, but not intermediate between the collection sites. These patterns confirm behavior observed in the laboratory: some whiteflies in a population are only trivial fliers whereas the remaining ones engage in migration and ignore vegetative cues for a period before landing. The maximum distance that individuals migrated was 4.8 km.

Studies on dispersal/migration have mostly been conducted in Arizona. Given this area is a desert agricultural community and does not represent the total universe where SLWF is a problem, studies are needed in areas such as Florida and Texas where factors impacting dispersal (i.e., wind movement intensity, direction and frequency) are probably significantly different from the desert habitat.

Reports of Research Progress
Section B. Fundamental Research–Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions

Co-Chairs: Jeff Shapiro and Judith K. Brown

Investigator's Name(s): J.K. Brown and G.K. Banks.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1, 1995 - December 31, 1995.

Analysis of the Capsid Protein Gene of Subgroup III Geminiviridae

The capsid protein (CP) gene is highly conserved among whitefly-transmitted (WFT) geminiviruses (Subgroup III, Geminiviridae) at both the amino acid and nucleotide sequence levels. The objective of this study was to investigate the CP gene as a diagnostic candidate for the identification of WFT virus species and for discrimination between virus species and virus strains. Degenerate primers were designed to flank an internal, conserved core region of the capsid gene, yielding a 550 base pair (bp) product that could be sequenced in a single reaction (Wyatt and Brown, 1994). This 550 bp viral capsid gene fragment was amplified by the polymerase chain reaction (PCR) and DNA sequences were obtained from over eighty field and/or greenhouse-maintained geminivirus isolates. Virus isolates were obtained from diverse biogeographic sites, worldwide, and representative host plant species. A dendrogram was constructed from sequence alignments of the WFT viruses and the analogous sequences of several non-WFT geminiviruses as outgroups. The calculated mean distances of the viral gene fragment sequences ranged from 0.05 to 0.57, suggesting that a range of species and subspecies were represented (Brown et al., 1994). In this analysis, Subgroup III geminivirus isolates were separated into several groups, based primarily on the geographical source of that isolate, e.g. of Old or New World origin, and then by subgeographies within a particular hemisphere, and/or by the plant host species from which the isolate was obtained.

Preliminary conclusions that can be drawn from these data are: (1) using this PCR approach, capsid gene sequences were obtained from Subgroup III geminiviruses detected in all suspect host plants, (2) the sequence of the core region of the capsid protein gene permits the sorting of Subgroup III geminiviruses into Old and New World groups with few exceptions, and (3) viral DNA sequence comparisons indicated that viruses which are grouped based on geography and host plant, are more closely related to one another than they are to members of other subclusters. These results suggest that this region of the viral capsid gene may, therefore, be useful in the classification of species versus strains within the Subgroup III geminiviruses. The addition of new sequences to the capsid gene database will facilitate the identification of a broader range of WFT geminiviruses and strains, as well the study of geminivirus relationships and phylogenies, both requisites to investigating geminivirus disease epidemiologies.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1, 1995 - December 31, 1995.

Mitochondrial 16S Ribosomal Subunit as a Subspecies/Species Marker for *Bemisa tabaci* (Gennadius): Evidence for a Species Complex

The whitefly *Bemisia tabaci* (Genn.) has become a serious pest and virus vector in agroecosystems, worldwide. Recent studies indicate biological differences among populations of *B tabaci* and evidence for genetic polymorphism at both the protein and nucleic acid levels (Bedford et al., 1994; Brown et al., 1995: in press; Costa et al., 1993; Frohlich et al., 1994). Populations of *B. tabaci* that exhibit measurable variability have been referred to as biotypes, races, strains. Several groups have proposed that the A and B biotypes may represent distinct *Bemisia* species (Costa et al., 1993; Bellows et al., 1994), and more recently, the application of 'species complex' has been suggested (Brown et al., 1995: in press) to account for the observed range of variability and associated reproductive isolation.

In this study, a target region within the mitochondrial 16S ribosomal subunit DNA(16S mt rDNA), with potential for discriminating at the species/subspecies level (Simon et al., 1994), was used as a molecular marker to assess variability among individual whiteflies. Five individuals from each of two whitefly genera (*Trialeurodes* and *Bemisia)*, inclusive of four *Bemisia* species (*berbericola, poinsettiae, tabaci, and tuberculata*), and ten well-characterized biotypes or populations of *B. tabaci* were investigated. The mt DNA target region was amplified by PCR using sequence-specific primers to obtain a 550 bp product, and DNA sequences were obtained.

Parsimony analyses indicate that *B. tabaci* is composed of at least four well-supported and distinct groups: three groups containing populations from the Old World, including the B biotype, and one containing all New World populations. Of the five individuals analyzed from the New World 'Jatropha biotype' (Bird, 1957), two clustered with individuals in an Old World grouping, and three with the New World cluster. Analysis of additional *B. tabaci* populations from diverse biogegraphic locales and from different host plants is in progress to expand this molecular data set. The results of these studies will ultimately permit useful phylogenetic inferences and predictions about evolutionary relationships between members of this polymorphic complex.

Investigator's Name(s): Allen Carson Cohen[1], T.J. Henneberry[1], and C.C. Chu[2].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1994.

Basic Feeding Relationships between Silverleaf Whiteflies and Host Plant Vascular Bundles by Period Covered: 1994

Studies of feeding dynamics revealed that nymphs of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring are obligate feeders on vascular bundles and that there are vast differences between different host plants as to the availability of vascular bundles to silverleaf whitefly nymphs. The relationship between nymphs and leaf vascular bundles was studied using 1) techniques of leaf clearing of intact leaves and 2) leaf sectioning. The relative abundance of vascular bundles was examined in six species of host plants that varied from highly preferred to tolerably acceptable. Included in order of acceptance were cantaloupe, cotton, hibiscus, broccoli, lantana and lettuce. The length of vascular bundle per 0.8 mm^2 of leaf surface ranged from about 10,000 µm in cantaloupe to 2800 µm in lettuce. Salivary sheaths were found to connect with vascular bundles in 100% of the intact nymphs examined by the staining and clearing technique. However only 64% of those examined by the sectioning technique appeared to be connected to vascular bundles. This indicates that the sectioning technique leads to a high rate of error, causing an underestimation of the importance of direct contact with vascular bundles. About 50% of epidermal stylet penetrations were through epidermal cells; the remaining 50% were intercellular. On cotton leaves, the distance between the point of labial contact with the leaf surface and the nearest point of the vascular bundle rarely exceeded 60 µm. Our studies show that while 50% of lettuce leaf-surface was beyond 60 µm of a vascular bundle, only 10% of cantaloupe leaf surface area was outside of the 60µm range. In cotton, mean distance from labium to the nearest point of the vascular bundle was 40.9 µm (SEM= 2.66, N= 50, range 0-80 µm). Seventy-eight % of the salivary sheaths went to single-filament vascular bundles, and nearly 20 % went to double filament bundles. Fewer than two % went to bundles with 3 or more filaments.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1994.

Feeding and Oviposition in Silverleaf Whiteflies on Cantaloupe, Cotton and Lettuce Leaves

The stylets of 1st instar nymphs were about 100 µm long, but they were rarely extended more than 75 µm to feeding sites. Older nymphs had longer stylet bundles than did the 1st instars, and adults' stylet bundles were about 200 µm long, though they were rarely extended beyond 80 µm into the plant. The vascular bundle geometry on cantaloupe allowed a "closest packing" arrangement of whiteflies where 38 1st instar nymphs could fit on a 1 mm^2 surface with mouthparts within reach; however, on lettuce the vascular bundle geometry would permit only 16 1st instar nymphs to reach the minor veins within the same surface area. Cotton vascular bundles were intermediate to those of cantaloupe and lettuce in terms of length of bundles per unit of leaf volume. Sugar processing enzymes were predominated by α-glucosidase with lesser amounts of α-galactosidase, ß-glucosidase and α-amylase in adult whiteflies from cotton. In adults from cantaloupe, α-galactosidase and α-glucosidase were prominent. There were no casein-, hemoglobin- or albumin-digesting proteinases in crude extracts from over 3 grams of adult whiteflies, while the same assays revealed that *Lygus hesperus* showed strong positive results from extracts from 1/10 of a pair of salivary glands from 10 mg individuals. If whiteflies do feed outside phloem tissue in non-vascular areas, they do not use proteinases to access nutrients, nor do they have proteinases as part of their digestive tract enzyme system.

Investigator's Name(s): Allen Carson Cohen[1], Robert T. Staten[2], and D. Brummett[1].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1994.

Why a Generalist (*Geocoris Punctipes*) Cannot Thrive on Whiteflies and Why a Specialist (*Serangium Parcesetosum*) Can: Or, Whiteflies as Junk Food

Predators can thrive on a single species of prey only if that prey provides all the essential nutrients. Whole carcass analysis of proteins and amino acids (in predators and prey) were used to compare the abilities of *G. punctipes* (a generalist) and *S. parcesetosum* (a specialist on whiteflies) to fulfill their nutritional requirements from whiteflies or pink bollworm eggs. All calculations were based on observed and averaged prey handling times and the intercatch intervals observed for each predator species. Using only biomass (weight) of predators and prey, we estimate that it would require about one hour per day for both predators to obtain adequate nutrients for growth and normal reproduction. However, if protein (rather than biomass) were the "currency," it would require about 20 hours for *G. punctipes* to "make its living." If methionine (an essential amino acid that is generally sparse in nature) were considered, it would take over 27 hours for *G. punctipes* to meet its requirements and about 6-7 hours for *S. parcesetosum* to meet its needs using whiteflies as prey. In terms of both protein and methionine requirements, both species of predators would profit better on pink bollworm eggs than they would feeding on whiteflies. Similar results were observed for other amino acids such as threonine, isoleucine, leucine and lysine; but results are most pronounced with methionine which we have shown to be very sparse in plant saps that are the feeding target of whiteflies.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1993 - 1994.

Unique Effects of Certain Polyethylene Sheets on the Behavior of *Bemisia tabaci* (Gennadius) and Spread of Viruses Vectored by this Insect

Field observations carried out during the summer of 1993 indicated that cucumbers and tomatoes grown in high tunnels covered with certain polyethylene sheets (IR Veradim, Ginegar plastic products, Israel) were highly protected against cucurbit yellow stunting disorder (CYSDV) and tomato yellow leaf curl virus (TYLCV) respectively. Both viruses are vectored by *Bemisia tabaci* Gennadius. A very high disease incidence (near 100%) was noticed in neighboring tunnels covered with the regular polyethylene sheets (IR Nectarine, Ginegar plastic products, Israel).

In the autumn of 1994 a field experiment was carried out in the Besor area of Israel where the whitefly population is reaching high levels and TYLCV disease incidence is very high. Tomatoes ®*Lycopersicon esculentum* var. 144) were grown in high tunnels (8x5m) covered with the compared plastics. Plants were sprayed once a week with an anti whitefly insecticide. Two months after transplantation the average TYLCV incidence under IR Veradim was 38% compared to 93% under the regular polyethylene sheets. The protection conferred by IR Veradim resulted also in a significant delay in plant infection and consequently to reduction in their symptom severity.

Monitoring the whitefly population under the compared plastics by yellow sticky traps, indicated a significantly lower number of whiteflies in tunnels covered with IR Veradim. However this finding might not fully explain the protection mechanism of this plastic.

Investigator's Name(s): H.S. Costa[1], D.M. Westcot[2] D.E. Ullman[2], R.C. Rosell[3], J.K. Brown[3], M.W. Johnson[2].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - August 1994.

Morphological Variation in the Bacterial Endosymbionts Within the Whitefly Genus *Bemisia*

It has been suggested that genetic changes in symbiotic organisms of insects may play a functional role in the development of new insect biotypes, resulting in insecticide resistance or in the ability to utilize a new host species. Congruent evolution between whiteflies and their respective endosymbionts at the whitefly genus level has been reported (BC Campbell 1993 Current Microbiology 26:129-132). One objective of this study was to examine whitefly endosymbionts to determine the degree of morphological variability that occurs in whiteflies among and within taxonomic subgroups of the genus Bemisia.

In a previous report (HS Costa, DM Westcot, DE Ullman, MW Johnson 1993, Protoplasma 176:106-115) the ultrastructure of the intracellular bacteria-like organisms of the B-biotype of *Bemisia tabaci* (proposed to be *Bemisia argentifolii*) were described. This study examines the ultrastructure of the bacterial endosymbionts of several populations of whitefly characterized as *B. tabaci* (*B. argentifolii*) and describes, in terms of morphology and relative frequency, the variability of the intracellular organisms. Consistent differences in endosymbiont morphology and relative numbers were observed between species and biotypes of *Bemisia*. B-biotype (*B. argentifolii*) individuals examined from three geographic locations (Hawaii, Arizona, and Florida) had two morphological types of micro-organisms, one pleomorphic(P) and one coccoid (C1). In contrast, *B. tabaci* A-biotypes (Arizona and Mexico) and *B. tabaci* Jatropha biotype (Puerto Rico) individuals had three morphologically distinct organisms, one pleomorphic type (P), and two coccoid types (C1 and C2). The A and Jatropha biotypes differed consistently in the relative frequency of individuals of each morphological type of organism. These observations suggest that different whitefly biotypes may have a complex of micro-fauna, some of which may be unique to each biotype or species.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - August 1994.

Observation of Virus-Like Particles in the Mycetocytes of *Bemisia tabaci*

At this time, populations of whiteflies presently described as members of the *Bemisia tabaci* complex have been characterized as several distinct biotypes based on host range, biological, biochemical and/or genetic differences (H.S. Costa, J.K. Brown, S. Sivasupramaniam, J. Bird, Insect Sci. Applic. 14, 255-266, 1993; J.K. Brown, D.R. Frohlich and R.C. Rosell. Ann. Rev. Entomol. 40, 511-534, 1995 in press). One of these populations, referred to as the Jatropha biotype or race (J. Bird, Tech. Paper Agric. Exp. Station 22, 35, 1957), was identified and provided by J. Bird, from a colony of whiteflies originally collected from the field in Puerto Rico from Jatropha gossypifolia, and maintained on J. gossypifolia in screen cages at the University of Puerto Rico campus, Rio Piedras, PR. This population has previously been referred to as the O biotype and the N biotype of *Bemisia tabaci.*

Many Homopterous insects, including whiteflies, have intracellular organisms that are considered symbiotic in nature, housed in specialized cells called mycetocytes. During comparative studies of the mycetocytes and bacteria from several populations of *Bemisia* spp. using transmission electron microscopy, large crystalline aggregates of isometric virus-like particles (VLP) were observed in individuals from a colony of *B. tabaci* Jatropha biotype. Virus-like particles were observed only in adult whiteflies from the Jatropha biotype, and were present in all Jatropha biotype individuals examined. The VLPs were icosahedral in shape, approximately 30 nm in diameter, and were observed scattered throughout the mycetocytes containing the endosymbiotic bacteria. Some crystalline arrays of particles were as large as 3 microns in diameter. The VLPs and aggregates were observed only in the cytoplasm of insect cells, never within the nuclei of insect cells or within the bacteria. Aggregates of particles were aligned along the exterior surface of insect cell nuclei suggesting an association with the whitefly rather than with bacterial cells.

The sweetpotato whitefly is a known vector of many plant viruses in the United States and Caribbean basin, however, the morphology of the virus-like particles observed in this study do not fit the description of any plant virus known to be transmitted by any whitefly species. The size and shape of the VLPs are similar, however, to those of picorna-like viruses reported to infect aphids and other species of insects. This is the first report of VLPs of any morphological type to be observed in whiteflies. Because mycetocytes are maternally transmitted to each developing egg, the presence of VLPs in mycetocytes suggests this virus may be transmitted transovarially. Examination of the specimens was restricted to the mycetome area, thus, the distribution of VLPs in other areas of the whitefly body remains to determined.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - January 1995.

The Relationship Between *Bemisia* Microorganisms and Honeydew Formation

Sugars in the honeydew produced by *Bemisia* and sugars resulting from fermentation of sucrose by homogenates of these insects, were analyzed by high performance liquid chromatography. Results suggest that the unusual disaccharide trehalulose, found in large quantities in *Bemisia* honeydew, is produced by obligate intracellular microorganisms residing in this insect's mycetomes. Some larger oligosaccharides in this honeydew may be produced by certain *Bacillus* spp. residing in or on the insects, but these bacteria are not involved in an obligate relationship with the whitefly. Attempts were made to locate living bacteria within *Bemisia* using light microscopy and vital stains.

Honeydew from both adult and immature *Bemisia* was collected from insects feeding upon artificial diets. A number of liquid and agar-based diets were investigated. The suitability of a variety of membranes was also investigated. Membranes tested included onion bulb epidermis and several synthetic products. HPLC analysis of the honeydew resulting from *Bemisia* feeding upon such diets showed that the trisaccharide melezitose was a component of nymphal but not of adult *Bemisia* honeydew.

Intact yellow mycetomes, isolated from surface-sterilized *Bemisia* nymphs, adult females and eggs, converted sucrose to trehalulose, glucose and fructose, but only insignificant amounts of other sugars. Homogenates of surface-sterilized adults fermented only a few sugars. They were found to be incapable of fermenting arabinose, cellobiose, dextran, fructose, galactose, glucose, mannose, melezitose, *N*-acetyl-D-glucoseamine, xylose and equimolar mixtures of glucose and fructose. Trehalulose was produced only from fermentations of sucrose and raffinose.

A number of antibiotics, lectins, BT toxins, fungal toxins and arthropod venoms were added to the artificial diets to determine if they could kill or influence the creation of honeydew by *Bemisia*. Only a very few of these had any effect on *Bemisia*, including two lectins, one fungal toxin and one venom.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - January 1995.

Activity of Natural and Semi-Synthetic Toxins on the Silverleaf Whitefly, *Bemisia argentifolii*, Using a Novel Feeding Bioassay System

An assay system has been developed for the adult silverleaf whitefly, *Bemisia argentifolii*. This practical and cost effective device is constructed from standard disposable laboratory materials. Whiteflies are harvested directly from the leaf and into a collection vial by aspiration, minimizing physical trauma to the insect. Insects so collected were fed through a nitrocellulose or cellulose mixed ester membrane on a diet of 27% sucrose alone or in an extract of zucchini (*Cucurbita moschata*). Mortality and honeydew production were scored. At 22-25°C and 50-55% relative humidity, control mortality remained at or below 10% over 48 hr of assay. The insecticide, Imidacloprid, was used to test the system. The system was then used to screen twenty-five naturally-occurring compounds with potential insecticidal activity against the whitefly. Bee venom and two of its components, a extract of the entomopathogenic fungus, *Metarhizium anisopliae*, and the natural insecticide/nematicide, Ivermectin, were found to be very toxic to adult *B. argentifolii*.

Investigator's Name(s): R. Diaz-Plaza.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: Research conducted from 1990 - 1993.

New Disease in Horticulture Crops in Yucatán, Mexico

A new disease of horticulture crops (tomatoes and peppers) was first observed in Yucatán, México in fall 1989. Symptoms in affected plants are severe stunting, curling, clorosis, foliar distortion, reduction of laminar tissue, epinasty, mosaic, poor root grow and sometimes purple streak in leaves. In fall 1989, tomatoes in Yucatán production areas were affected with yield losses estimated at 80-100%. In pepper the problem is like in tomato, but the farmer is losing his germplasm because they could not obtain good fruit to select the seed.

Symptoms seen in the field were reproduced in greenhouse by whitefly transmission from affected plants to healthy tomatoes and pepper. The disease was transmitted by grafting but it could not be transmitted mechanically or by seed either in tomatoes or pepper. Some differential plants used did not develop symptoms.

Looking for cellular inclusion it was observed two types, crystalline and dense-circular bodies, both cytoplasmic and near the nucleus, none of two types of inclusion had been related with some viruses yet. Recently, it was running a DNA probe with Southern Blot Test founding one geminivirus in samples of tomatoes, pepper, and a wild weed.

Investigator's Name(s): James E. Duffus, Hsing-Yeh Liu, and Gail C. Wisler.

Affiliations & Locations: USDA-ARS, Salinas, California.

Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: October 1, 1993 - September 30, 1994.

Distribution of Tomato Infectious Chlorosis Virus in California

A virus disease of tomato, first described in 1994 from southern California(1), has now been found in northern California. Tomato infectious chlorosis virus (TICV), first found in the Orange County area of southern California in 1993, induced interveinal yellowing, necrosis and severe field losses in the Irvine hills and valley region. The virus was transmitted by *Trialeurodes vaporariorum* (Westwood) but not by either the A or B biotypes of *Bemisia tabaci*.

Leaf dips and purified preparations showed flexuous filamentous particles similar to closteroviruses. Field and laboratory observations have established that the virus also occurs in commercial greenhouses and field plantings in San Diego County and is established in wild hosts in the southern California region. The virus has recently been found in high incidence in research greenhouses in the Davis area of California. These occurrences have been confirmed by transmission and serological tests.

(1) Duffus, James E., Liu, H.Y. and Wisler, G.C. A new closterovirus of tomato in southern California transmitted by the greenhouse whitefly (*Trialeurodes vaporariorum*). Phytopathology 84:1072-1073. 1994.

Investigator's Name(s): John S. Hu and Diane E. Ullman.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1994.

Detection and Characterization of Geminiviruses in Hawaii

Geminivirus was first identified in Hawaii in 1993. The virus was detected in the widely distributed ornamental plant lantern 'ilima (*Abutilon hybridum*) using ELISA and PCR assays. In a survey for geminiviruses, vegetable and ornamental plant samples were tested using indirect ELISA with a monoclonal antibody against a shared epitope of whitefly-transmitted geminiviruses (MAb 3F7, E. Hiebert, University of Florida). Samples were collected from the islands of Hawaii, Maui, and Oahu from symptomatic plants with whitefly (*Bemisia tabaci*) infestations. Five plant species, lantern 'ilima, abutilon, kabocha squash, zucchini, and papaya squash were positive in ELISA tests for geminiviruses. The lantern 'ilima, abutilon, and zucchini samples also tested positive with polymerase chain reaction (PCR) using degenerate primers (PAL1v1978 and PAR1c715 for component A, PV494 and PC1048 for component B, D. P. Maxwell, University of Wisconsin). PCR products were cloned and sequenced. Sequence analysis results show that lantern 'ilima virus is more closely related to the published abutilon mosaic virus (approximately 93% sequence identity). However, preliminary sequence data show that the PCR products from squash samples do not share significant sequence identity with other geminiviruses. In addition, the sweetpotato whitefly strain B was not able to transmit lantern 'ilima geminivirus and the putative geminiviruses in squash plants.

Investigator's Name(s): Stefan T. Jaronski[1] and Kim Hoelmer[2].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: May - July 1994.

Impact of *Beauveria Bassiana* Mycotech BB401 and *Paecilomyces Fumosoroseus* Mycotech PFR612 on Natural Enemies of Silverleaf Whitefly in Spring Cantaloupe and Cotton in Imperial Valley, CA

During field trials of *Beauveria bassiana* Mycotech Strain BB401 and *Paecilomyces fumosoroseus* Mycotech Strain PFR612 in late-season, spring cantaloupe and in cotton in the Imperial Valley (reported elsewhere) levels of predation and parasitism of SLWF nymphs were examined. These trials are part of a joint USDA/ARS, USDA/APHIS and Mycotech Corp. effort to develop fungal biocontrols of *Bemisia* spp.

The canteloupe plots received four applications of 1×10^{13} or 2×10^{13} conidia per acre of each fungus at approximately four-day intervals. Action of natural enemies on SLWF was mainly in the form of predation, primarily *Geocoris* sp. and *Chrysoperla* sp. based on observation of insects in the field. Eighteen days after commencement of fungal applications, predation and parasitism levels were 11-21%, with no significant differences between untreated control, carrier control and fungus-treated plots. No fungus-killed predators were observed.

Cotton plots received five applications of 2×10^{13} conidia/acre of the two fungi at 4-5 day intervals. In this trial detailed separate observations were made of parasitism and predation levels. Predation of nymphs (primarily by *Orius* sp.) by Day 26 of the trial had reached 12-25%, with no significant difference between control and fungus-treated plots. Rates of parasitism ranged from 3-9% in the fungus treatments compared to 11% in the controls. The differences between fungus-treated and control plots were not significant (Tukey's HSD test, $p = .05$, using arsin $\sqrt{\%}$-transformed data).

These data indicate that both fungi, when repeatedly applied at rates of 1×10^{13} or 2×10^{13} conidia/acre, had no adverse impact on the action of the natural enemy populations present in the test plots.

Investigator's Name(s): Cynthia S. LeVesque[1], Thomas M. Perring[1], Linda L. Walling[2], and Anthony A. James[3].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: July 1994 - January 1995.

Characterization of Sex-Specific Gene Expression in Silverleaf and Sweetpotato Whiteflies by Differential Display

The use of differential RNA display is being utilized in the identification of genes involved in sex- and adaptation to host plant-specific gene expression in the silverleaf and sweetpotato whitefly species.

Clonal colonies of both the silverleaf and sweetpotato species have been developed on bean from single virgin mating pairs. Approximately 1000 individuals have been used from each of these clonal colonies to initiate both silverleaf and sweetpotato colonies on squash and tomato. The technique of differential RNA display is being utilized to compare the gene expression profiles between males and females isolated from the bean colonies. These comparisons will provide important tools needed in the development of transgenic insects. Comparisons of gene expression profiles will also be made between colonies of the same species developed on the three host plants, as well between colonies of the two species developed on the same host plant. These comparisons should allow us to identify and isolate genes involved in adaptation to host plants and the induction of the plant developmental disorders, squash silverleaf and tomato irregular ripening.

Investigator's Name(s): Cynthia S. LeVesque[1], Thomas M. Perring[1], Linda L. Walling[2], and Marylou Polek[3].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: September 1992 - January 1995.

Induction of Tomato Irregular Ripening by Silverleaf Whitefly Feeding

Studies were conducted to identify ripening- and defense-related genes targeted in the induction of irregular ripening in tomato by silverleaf whitefly feeding.

We have evaluated the expression of ripening-related genes in fruit from plants with low, moderate and high infestations of silverleaf whitefly grown in the field in 1992. Polygalacturonase (PG1) and E8 are two ripening related genes normally expressed at high levels in tomato fruit from the mature green stage, when locule contents are fully gelled, to the ripe stage. RNA blots were hybridized to ^{32}P-labeled PG1 and E8 probes. PG and E8 mRNAs levels were related inversely to the severity of irregular ripening symptoms and the density of whiteflies to which plants had been exposed. These mRNAs were undetectable in fruit from plants infested with the high level of silverleaf whitefly, whereas the PG1 and E8 mRNAs were easily detected in fruit from plants from the low infestation treatment. The level of D21 transcripts also was determined since it encodes an mRNA that is fruit-specific but unrelated to ripening. Normally, the D21 transcript is detected and not modulated throughout ripening. D21 transcripts were detected in all fruit, but its levels were unaffected by whitefly infestation. ACC synthase is one of the key enzymes involved in ethylene synthesis. The level of ACC synthase mRNA was undetectable in all of these RNA preps. The transcript levels for the actin gene (a control), was uniform for all samples.

A second experiment was conducted under greenhouse conditions during the summer and fall of 1994. In this experiment, plants were trellised and pruned to the main stem and a single lateral. Silverleaf whiteflies were confined in sleeve cages on leaves of treatment plants, and leaves on control plants were similarly sleeved. Throughout the course of the experiment the fruit harvested was carefully mapped in relation to feeding insects. A subset of fruit was sampled for ultrastructural studies to determine if irregular ripening involves the formation of a novel plastid form. The levels of ripening-related gene mRNAs are being measured in the fruit samples harvested. During the course of the experiment, a subset of treatment and control plants were used to asses the impact of silverleaf whitefly feeding on the expression of genes related to defense responses. Leaves on treatment and control plants, above sleeved leaves, were mechanically wounded or infected with *Pseudomonas syringe* pv tomato. The level of transcript for leucine aminopeptidase, a protein involved in signal transduction in both wounding and defense responses, was repressed in wounded or infected leaf tissue which was in close proximity to sleeve cages on silverleaf whitefly infested plants. The ability to modulate host-plant defense responses may be an important mechanism in the development of the silverleaf whitefly's adaptive advantage.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1994.

Oviposition by Silverleaf Whitefly on Tomato: Effects of Leaf Factors and Insecticide Residues

Ovipositional preference based on leaf age (old vs. young), height (high vs. low), surface orientation (abaxial vs. adaxial), and the presence of insecticidal residues was determined for silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (formerly *Bemisia tabaci* (Gennadius), Strain 'B'). Two-leaflet artificial plants were used to study the effects of leaf age, height and surface orientation in choice and no-choice tests. Results showed that whiteflies preferred young leaves to old leaves for oviposition, although this preference was overridden by reversing normal leaf positions, i.e., placing old leaves high and young leaves low. In contrast, preference for the lower (abaxial) leaf surface was not reversed by reversing orientation, although oviposition on the upper (adaxial) surface was increased by this procedure.

The effects of insecticide residues on oviposition were studied by exposing whiteflies to individual insecticide-treated tomato leaves. Biorational insecticides tested were: Sunspray Ultra Fine Oil (a mineral oil) at 0.125, 0.25, 0.5, 1.0 and 2.0% (vol./vol.); M-Pede (an insecticidal soap, 49% potassium salt of a naturally derived fatty acid, Mycogen Corp., San Diego, CA) at 0.5, 1.0, 2.0, 4.0 and 8.0% (vol./vol.); *Nicotiana gossei* extract (acylsugar) at 0.1, 0.2, 0.4, 0.8 and 1.0% (wt./vol.). Bifenthrin (Brigade 10WP, pyrethroid, FMC Corp., Middleport, NY) at 0.015, 0.03, 0.06, 0.12 and 0.24g (AI)/l was used for comparison and water (reverse osmosis, 7 ppm dissolved solid) was used as a control. Interactions among leaf-ages, leaf-heights and insecticide residues were studied on artificial plants. Fewest eggs were found on young leaves treated with Sunspray oil, followed by bifenthrin, M-Pede and *N. gossei* extract in choice and no-choice tests. Fewest eggs were found on the leaves treated with Sunspray oil, followed by bifenthrin, M-Pede and *N. gossei* extract although differences between rates of particular insecticides were generally not significant. The effects of leaf age and leaf height were overridden by bifenthrin and Sunspray oil, whereas M-Pede overrode leaf-age effects, but not leaf-height effects.

Investigator's Name(s): Prem Mehta[1], Jeffrey A. Wyman[1], M. K. Nakhla[2], Douglas P. Maxwell[2].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - May 1994.

Detection of Two Tomato-Infecting Geminiviruses in Individual *Bemisia tabaci* (Homoptera: Aleyrodidae) Adults

Mixed infections of geminiviruses are known to occur in vegetables; however, the ability of *Bemisia tabaci* to acquire and transmit more than one geminivirus at a time has not been demonstrated. Infectious clones of tomato yellow leaf curl geminivirus (TYLCV) from Egypt and tomato mottle geminivirus (ToMoV) from Florida were agroinoculated individually and together into healthy tomato plants. After 15 days, B-biotype *B. tabaci* adults were fed on these plants for an acquisition-access period of 24 h and then transferred to healthy tomato seedlings for a 72 h inoculation-access period (IAP). Following this IAP, individual whiteflies were examined for viral DNA by a PCR assay with virus-specific primers. Individuals collected from singly infected plants had either TYLCV or ToMoV, while individuals fed on tomatoes with mixed infections contained both viruses. After inoculation with the viruliferous whiteflies, tomato plants were infected with either virus alone or both as expected. Our data show that individual *B. tabaci* adults can acquire two geminiviruses from a source plant with a mixed geminivirus infection and that *B. tabaci* was able to transmit ToMoV and TYLCV from tomatoes infected with clones of these geminiviruses.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - January 1995.

Competitive Displacement of Sweetpotato Whitefly by Silverleaf Whitefly

As studies distinguished two species of *Bemisia*, an apparent contradiction was that the two were not found in sympatry. By the time it was recognized in California in 1990 it was difficult to find *Bemisia tabaci* (Gennadius) present in the desert southwest. This led to the speculation that *Bemisia argentifolii* Bellows and Perring has so effectively competed with *B. tabaci* that it has displaced it.

The assumptions and theories underlying the competitive exclusion principle state that "closely related organisms having similar habits or life forms often do not occur in the same places." (Odum, E.P. 1971 Fundamentals of Ecology, 3rd Ed.). Odum went further to say that "If they do occur in the same place, they use different food, are active at different times, or are otherwise occupying somewhat different niches." Applying Odum's ideas to the *Bemisia* issue in southern California, we first recognized that the known host range of *B. argentifolii* completely overlapped the recorded hosts for *B. tabaci*. Perhaps more importantly than utilization of the same host plants is the seasonality of those hosts and the ability of *B. argentifolii* to maintain large densities through the winter; *B. tabaci* overwintered (November through April) on only a few winter annual and perennial plants. *B. argentifolii* was present at times when *B. tabaci* was rare.

Another aspect mentioned in Odum's (1971) discussion is that different niches would allow co-existence of the two species. For these two species, evidence exists that suggests that the two share the same niche (for example, adults and immatures of both species occur predominantly on abaxial leaf surfaces, and females of both species prefer young leaves for oviposition. This suggests that the two species would be closely associated during the time in which both were present in southern California. In a situation of greater abundance of *B. argentifolii* during the early spring and early summer months, the fact that it has an ovipositional rate of nearly twice that of *B. tabaci* (Bethke et al.. 1991. Ann. Entomol. Soc. Am. 84: 407-411) and that it feeds at a higher rate than *B. tabaci* (Byrne & Miller. 1990. J. Insect Physiology 36: 433-439) provides a tremendous adaptive advantage for this newly introduced species.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1994 - January 1995.

Mating Behavior of *Bemisia* and its Relationship to Competitive Advantage

As part of the research to determine species designation, Perring et al. (1993, Science 259: 74-77) evaluated the mating behavior of the two whiteflies when placed together. Experiments showed that males and females of the same species courted and copulated. *Bemisia argentifolii* Bellows and Perring spent an average of three times the amount of time in pre-copulation courtship than did *Bemisia tabaci* (Gennadius). Additionally *B. argentifolii* spent less time in copula than *B. tabaci*. These data indicate that another biological difference exists between these species, a difference that could influences reproductive success when populations of the two species are in sympatry.

Perhaps more significant was when males of *B. argentifolii* were paired with females of *B. tabaci*, and visa versa. Whiteflies placed in these interspecific crosses courted each other, but never copulated. Interestingly, male *B. argentifolii* courted female *B. tabaci* longer than *B. tabaci* males courted *B. argentifolii* females. This greater "persistence" of male *B. argentifolii* may result from the biological difference between the species noted above (i.e. *B. argentifolii* males are adapted to longer courtships with their own females than *B. tabaci* males with their females). In an ecological sense, the consequence of this interspecific interaction is that *B. argentifolii* compete with *B. tabaci* males for *B. tabaci* female resource. With numbers of *B. argentifolii* far exceeding *B. tabaci* in the spring and early summer, this female resource already is severely limited. Coupled with competition for available food, year round survival of *B. argentifolii* in high numbers, and the other biological parameters that favor *B. argentifolii* (see abstract by Perring & Farrar in this section) it is not surprising that *B. tabaci* is difficult to find in areas infested with this new whitefly species.

Investigator's Name(s): R. C. Rosell[1], I. D. Bedford[2], P. G. Markham[2] D. R. Frohlich[3], and J. K. Brown[1].

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 - December, 1994.

Morphological Variation in the Fourth Instar of Whitefly Populations in the Genus *Bemisia*

The taxonomy of whiteflies is based primarily on morphological characters of the "pupal case" of the fourth nymphal instar. In *Bemisia tabaci*, profuse variability in these characters has led to confusion regarding the taxonomy of the genus and ultimately lead to the synonimization of eighteen species into the taxon. The recent introduction of an exotic biotype of *B. tabaci*, tentatively referred to as the B biotype, has prompted a renewed interest in the taxonomy and phylogeny of whiteflies, with an emphasis on the genus *Bemisia*. Several morphological differences in the pupal cases of the A and B biotypes were cited, in part, as evidence of a new whitefly species, *Bemisia argentifolii* Bellows & Perring. The presence of anterior submarginal setae four (ASMS 4), broadened anterior wax margins, and posterior wax margins that extend beyond the boundaries of the caudal setae were described as definitive morphological differences for the separation of the A biotype (*B. tabaci)* from the B biotype (*B. argentifolii*). A major drawback to these criteria for the species separation is that other populations of *B. tabaci* exhibit substantial variability not only in pupal case morphology, but also in general esterase profiles, mating behaviors, RAPDs patterns, and 16S mitochondrial DNA sequences which indicates a greater degree of morphological plasticity and genetic polymorphism than previously realized. The objective of this research was to examine, by cold stage scanning electron microscopy, specific morphological characters of the pupal cases of *Bemisia* individuals from different populations/biotypes obtained from representative biogeographic locations, worldwide, and from different host plant species. To determine if these morphological characters are useful in taxonomic considerations, these data were analyzed using parsimony methods.

The results of this study indicate that the ASMS 4 were generally absent in individuals from non-B biotypes and from *B. argentifolii*, but were present in most A biotype individuals and in other New World populations of *B. tabaci* and in *B. hancockii*. Anterior wax margins were large and posterior wax fringes were extended in New World populations and in two Old World populations. In the B biotype populations examined, the anterior wax margins were only somewhat reduced and the posterior wax margins were extended beyond the caudal setae. Thus, these morphological characters are not consistently unique to the B biotype. Parsimony analyses of quantitative data for individuals from all *B. tabaci/B. argentifolii* populations indicated that the populations could not be separated based solely upon the morphological characters examined. Further when several biological characters were included in these analyses, no obvious separation of the populations into independent groups was observed. Measurable biological differences among geographically isolated populations of *B. tabaci* have led to a proposed working hypothesis that *B. tabaci (B. argentifolii*) is a species complex. However, the observations from this study suggest that morphological characters are not useful as exclusive traits by which to identify or classify members of the *Bemisia tabaci* complex at the species or subspecies levels.

Investigator's Name(s): James H. Tsai and Kaihong Wang.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1993 - 1994.

Characteristics of Bean Golden Mosaic Virus Transmitted by Silverleaf Whitefly (*Bemisia argentifolii*) in South Florida

Recently, we completed a study on the transmission characteristics of a Florida isolate of bean golden mosaic virus (BGMV) by *B. argentifolii*.

The acquisition efficiencies by individual silverleaf whitefly adults (n = 31-121) were 27.08, 27.27, 38.71, 48.76, 67.08, and 72.92% after 2, 4, 8, 24, 48 and 72-hr acquisition access periods, respectively. The respective inoculation efficiencies by single adults after 1, 4, 8, 3.30, 21.88, 38.24 and 67.64%. The minimum inoculation time by individual adults was found to be at 0.5 hr. Viruliferous adults retained BGMV until the insect's death. Of several cultivars of *Phaseolus* beans and legume spp. tested, only Garden bean (*Phaseolus vulgaris* L. cv. Podsquad) and *Galactia* sp were found to be susceptible to this BGMV isolate.

Investigator's Name(s): Don C. Vacek and Raul A. Ruiz.

Affiliations & Locations: USDA, APHIS, PPQ, Mission Biological Control Laboratory, Mission, TX.

Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions; and Section D: Biological Control.

Dates Covered by the Report: 1993 and 1994.

RAPD-PCR Identification of Natural Enemies of SPWF

The integration of molecular genetic techniques into quarantine importation and culture of exotic natural enemies has enhanced the implementation of biological control of *Bemisia tabaci*, biotype B (SPWF). The Mission Biological Control Laboratory (MBCL) serves as the primary quarantine for USDA in the importation of natural enemies of SPWF. Voucher specimens of the natural enemies imported and cultured in the quarantine laboratory are provided to both systematists and the MBCL Genetics Diagnostics Laboratory. While systematic determinations are in progress, specimens are rapidly and reliably identified with genetic fingerprints produced by the technique of RAPD-PCR (randomly amplified polymorphic DNA-polymerase chain reaction). The *Encarsia* populations will most likely be classified as the following species: *E. formosa*, *E. transvena*, *E.* nr. *strenua*, *E. pergandiella*, and *E.* nr. *pergandiella*. A total of 34 *Encarsia* populations from 12 countries (Africa, Cyprus, Egypt, Greece, India, Malaysia, Nepal, Philippines, Spain, Taiwan, Thailand, and U.S.A.) were divided into 13 RAPD pattern groups which generally followed species designations, where available. The *Encarsia* patterns were distributed as follows: three unique to the U.S.A., four unique to Southeast Asia, four not found in U.S.A. and Southeast Asia, one not found in the U.S.A., and one widely distributed. A total of 15 *Eretmocerus* populations (representing *Eretmocerus spp.* and several undescribed species) from 6 countries (Egypt, India, Spain, Taiwan, Thailand, and U.S.A.) were divided into 9 RAPD pattern groups. The *Eretmocerus* patterns were distributed as follows: four unique to the U.S.A., three unique to Southeast Asia, and two not found in U.S.A. and Southeast Asia. Genetic fingerprinting with RAPD complements systematic determinations and is an effective way to identify insects for delivery of a biological control program.

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Research & Implementation Area: Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1992 - 1994.

Correlations of Silverleaf Whitefly Feeding and Oviposition Behaviors with AC Electronic Feeding Monitor Waveforms

Electronic feeding monitor waveforms produced by adult female silverleaf whiteflies feeding and ovipositing on lima bean leaves were correlated with specific behavioral events. Four different waveforms were identified that were correlated with 1) intercellular penetration of the stylets through parenchyma leaf tissue; 2) partial stylet withdrawal and re-insertion of the stylets; 3) phloem sap ingestion; and 4) oviposition. A fifth waveform may be associated with xylem sap ingestion, but requires further study for verification. With these behavioral correlations established, the electronic feeding monitor technique can be used to study details of whitefly feeding that are not obtainable by any other technique. Silverleaf whitefly began ingesting phloem sap a minimum of 3.2 min and a mean of 15.6 min (n=99) after the initiation of a probe. Surprisingly, few eggs (only 2% of total number of eggs laid; n=133) were laid while females were ingesting phloem sap. Most (58%) of the eggs were laid when the stylets were in the mesophyll of the leaf and another 21% of the eggs were laid when the insects were not probing at all. Most eggs that were laid during a probe were laid within the first minute of the probe, indicating relatively shallow penetration of the stylets in the plant tissue. Furthermore, most probes, during which oviposition occurred, terminated within 30 sec of oviposition, suggesting that the insects' motivation for that particular probe was to oviposit; and once oviposition occurred, the probe was terminated, rather than continued on to ingestion.

TABLE B. Summary of Research Progress for Section B – Fundamental Research – Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
B.1 Studies of feeding behavior: sensory receptors, ultrastructure, morphology, digestive physiology; intra- and interspecific competition.	Yr. 3: Continue in-depth studies begun earlier; investigate relationship between endosymbionts and nutrition; use feeding monitor to screen for host resistance and response to residue of pesticides and natural products.	X		Behavioral and histological studies on feeding have continued. Observations on nymphs indicate modes of stylet penetration, sheath formation, and feeding. Nymphs are key to understanding direct effects on plants, due to their virulence in contrast to that of adults. Several lines of research indicate potential for developing technologies to deter or reduce feeding and oviposition of adults.
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction.	Yr. 3: Continue basic studies; identify potential weak links for further research: i.e., genetic and physiological bases for host selection, habituation, switching, etc.	X		Sugars in excretion products from nymphs have now been well characterized. Results of chemical studies are being employed in attempts to alleviate stickiness of cotton enzymatically. Host selection studies and host effects on tritrophic interactions have shown definite correlations between host plant and whitefly population levels. Cuticular waxes have not shown use for taxonomic identification at the species level [NELSON]. Whiteflies respond to use of insecticides, oils, and surfactants with regard to their oviposition behavior, and successful oviposition is crucial to high whitefly populations.
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species, genetics and genetic diversity. Develop dsRNA and cDNA probe.	Yr. 3: Continue systematic analysis of SPW; develop rapid identification systems.	X		Diagnostics for natural enemy (especially parasitoid wasp) identification are being successfully employed. Many species can be differentiated within the genera, *Encarsia* and *Eretmocerus*, using genetic fingerprinting by RAPD-PCR. Discovery of natural enemies and tracking of their success once released will be expedited by this technique.
B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Yr. 3: Continue analyses of *Bemisia* species, define taxa and begin phylogenetic analysis.	X		Although *Bemisia* systematics are still in a state of ferment, both molecular and morphometric analyses are contributing to a better understanding of the overall relationships among biotypes. Analyses have begun with attempted resolution of differences between the A and B biotypes (*B. tabaci* and *B. argentifolii*, respectively), and now encompass the genus *Bemisia* as a whole, worldwide. Eventually, the studies may result in a global revision of the genus.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
B.5 Identify and define SPW toxicogenic effects.	Yr. 3: Define affected plant target molecules and molecules mediating systemic response. Use probe to localize source of dsRNA.	X		While precise mechanisms of direct (toxicogenic) effects of whiteflies (especially *Bemisia argentifolii*) on host plants have not been discovered, some of the phenomena have now been histologically defined and nymphs identified as the source. New approaches to the molecular bases of plant syndromes such as tomato irregular ripening and squash silverleaf are now being applied. One such method that shows promise is the differential display of messenger RNA.
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Yr. 3: Analyze variability of SPWe genome in different SPW biotypes via RFLP, PFE and hybridization with SPW dsRNA probe.	X		Microscopic analysis of endosymbionts has begun to define specific forms of symbiotic bacteria associated with the mycetomes of *Bemisia*, and to define differences among genetically defined populations. The effects of symbiont type on the host insect and of antibiotic treatment of symbionts are now understudy. The latter shows a detrimental effect on the whitefly and decrease in feeding effects with the death of symbiotes. Other biochemicals are being tested for effect on endosymbionts and interference with honeydew production.
B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diag-nostics and resistance; virus-vector specificity and interactions.	Yr. 3: Continue developing virus diagnostics; molecular comparisons of sequence data, relations; continue cloning and characterization; continue virus-vector studies. Develop diagnostic tests for epidemiological purposes; clones for (injured) resistance.	X		Diseases of vegetable and ornamental crops due to the whitefly-transmitted geminiviruses were observed in Florida, Hawaii, and Yucatan, Mexico. One non-geminivirus, the tomato infectious chlorosis virus of tomato was described for the first time in California during 1994. Polyethylene sheets was evaluated as barriers to reduce the incidence of disease due to tomato yellow leaf curl virus in Israel (TYLCV-Is). A PCR technique was developed for detection and identification of whitefly transmitted geminiviruses.

Research Summary

Section B: Fundamental Research–Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions

Compiled by: J.K. Brown and J.P. Shapiro

B.1 Studies of feeding behavior: sensory receptors, ultrastructure, morphology, digestive physiology; intra-and interspecific competition.

Knowledge of feeding behavior has advanced significantly, especially through histological study of nymphal feeding. Successfully established nymphs were shown to always possess a stylet sheath attached to a vascular bundle in leaves. Egg pedicels showed intracellular communication with plant cells and absorption of liquid by this route. Paths of penetration of nymphal and adult stylets into leaves and vascular bundles were traced. The abundance of vascular bundles in various plant cultivars and species was correlated with the abundance and success of nymphs. Further histochemical characteristics of exuded salivary material and enzymes were defined. Potential targets for application may include alteration of plant leaf surface chemistry to repel feeding and oviposition, biochemical disruption of stylet sheath formation, inhibition of some enzymes that account for damage at the feeding sites, or increasing the viscosity of sap to reduce rates of feeding. AC feeding monitors were able to correlate ovipositional activity with adult feeding patterns, indicating that feeding patterns of the female may actually indicate more about ovipositional preferences and site location than about nutrition of the adult. Roles of specific sensory receptors are still undefined. Research further showed that nymphs are responsible for several of the phenomena that most critically affect crop plants (see B.5, below).

B.2 Studies of biochemistry, physiology, nutrition, development and reproduction.

Since most problems in cotton and some other crops are produced by exudates that contain sugars, nymphal excretion is critical. From studies on the biochemistry of sugar composition in exudates, potential applications have focused on enzymatic digestion of sugars in cotton after picking and feeding inhibition or alteration to reduce the amount or quality of exudate. Work on enzymatic digestion of sugars continues toward potential commercial development. Characteristics of some specific whitefly populations have been shown to influence impact of exudates on cotton.

While earlier work on parasitism mostly ignored the contribution of host plant diversity, the role of specific host plants in determining the success of parasitoids (or lack thereof) is now being studied. Observations may indicate reasons for failure of particular parasitoids when introduced from certain plants. Definite effects of host plant on parasite searching and oviposition behavior were shown.

Analyses of cuticular waxes from adult and immature whiteflies did not effectively differentiate among biotypes or even species, but effectively identified to the genus level. Composition of these waxes may play a role in interactions of parasitoids and predators with the whitefly.

Insecticide residues were found to influence oviposition on tomato leaves, with Sunspray oil, bifenthrin, M-Pede, and *N. gossei* extract resulting in fewest to most eggs laid, respectively. Leaf age and position on the plant influenced oviposition rates.

B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species, genetics and genetic diversity. Develop dsRNA and cDNA probe. (see B.6)

A rapid diagnostic molecular diagnostic method has been developed by which to differentiate select natural enemies of the *B. tabaci* complex. Included in the analysis were two genera of natural enemies collected from 12 different countries during foreign exploration efforts in both Old and New World sites. Genetic fingerprints have been established using RAPD-PCR. This method now permits the identification of five distinct *Encarsia* spp. and nine polymorphic *Eretmocerus* populations. Genetic markers will be invaluable for rapid identification of natural enemy populations collected in the future from other world sites, in facilitating the monitoring of natural enemy populations maintained in colonies for evaluation, and in determining the identity and distribution of natural enemies released into field situations for prospective control of *Bemisia* spp.

B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods. (see B.6)

Morphometric analysis of whitefly pupae, or fourth instar immatures, was conducted to assess the utility of morphological characters for identification and taxonomic considerations of *Bemisia* spp. at species and subspecies levels. Characters examined were those cited recently as definitive differences for separation of the A and B biotypes as distinct species, *B. tabaci* and *B. argentifolii*: The anterior margin setae four (ASM4), presence of broadened

anterior wax margins, extended posterior wax margins. Examination of individuals (n=10) per population by transmission electron microscopy (TEM) and subsequent parsimony analysis of data indicated the ASM4 were generally absent from non-B biotypes, and from *B. argentifolii*, but were present in most A biotypes and non-A New World populations. The large size of anterior wax margins and extension of the posterior wax fringes were not unique to either New or Old World populations, and thus are not considered distinctive morphological characters for consistent differentiation of the A from the B biotype as proposed. Parsimony analysis of these data indicated that the *Bemisia* examined here could not be separated into separate species, based solely on morphological characters.

The same collection of *B. tabaci* was evaluated with respect to DNA sequence similarity of a gene fragment targeted in the mitochondrial 16S ribosomal subunit, postulated to constitute a region that permits discrimination at the subspecies level. Four major subgroups were supported by parsimony analysis: three groups from the Old World (including the introduced B biotype), and one group containing all New World (including the A biotype) populations assessed. Based on 16S mtDNA analysis of additional populations, more subgroups may be feasibly supported. These collective findings, and data published concerning virus-vector capabilities, mating compatibilities/incompatibilities, and genetic polymorphism at the protein (general esterases) and nucleic acid (via RAPD analysis) levels, strongly support another currently proposed working hypothesis, that populations presently upheld as *Bemisia tabaci* and/or *B. argentifolii* are members of a *B. tabaci* complex.

B.5 Identify and define SPW toxicogenic effects.

Direct (toxicogenic) effects of the B-biotype *Bemisia (Bemisia argentifolii)* whitefly are expressed as tomato irregular ripening (TIR), squash silverleaf (SSL), and other phenomena such as vein clearing in the Brassicae. To date, histological and biochemical approaches have defined SSL, but examination of molecular effects of *Bemisia* is just commencing. At this meeting, a new approach to defining TIR was reported, through comparative analysis of RNA expression in whitefly-infested vs. uninfested tomatoes. Differential display, a recently developed technique that utilizes reverse transcription and PCR amplification of transcripts, was employed. In response to challenge by *Pseudomonas syringae* bacteria, expression by plants of the defensive gene *LAP* was suppressed near infestations of immature whitefly. Insensitivity of tomato fruit to ethylene exposure in TIR may relate to suppressed expression of the E8 gene for "perception" of ethylene. Expression of polygalacturonase, a gene mediating some aspects of ripening, was also reduced.

Altogether, physiological and molecular approaches to direct effects of *Bemisia* on host plants are progressing slowly due to lack of funding and emphasis on more applied (technological) approaches to *Bemisia* population control. Lack of involvement of plant scientists in this research also contributes to low momentum.

B.6 Characterize SPW endosymbiote influence on metabolism, host range, and biotype formation.

Morphological variants of putative endosymbionts were identified in populations of the *B. tabaci* complex. Differences in number, morphology, and relative frequency were documented. Three morphoforms were observed among the whiteflies examined: coccoid C1, coccoid C2, and a pleomorphic P form. Two forms, C1 and P, were associated with the B biotype (also *B. argentifolii*), whereas all three forms, C1, C2, and P, were present in two New World populations, the A biotype and the Jatropha biotype from Puerto Rico. In addition, virus-like particles (VLPs') of approximately 30 nm in diameter were observed by TEM in the monophagous Jatropha biotype of *B. tabaci* from Puerto Rico. These VLP's were associated with mycetocytes containing endosymbiotic bacteria. This is the first report of VLP's associated with this genus of whitefly; it is not known if the virus is pathogenic to the whitefly host. The significance of these findings is currently under study.

The unusual sugar, disaccharide trehalulose is found in large quantities in the honeydew of the whiteflies, and is postulated to be produced by an interaction between the whitefly and the obligate, intracellular microbes housed in the mycetomes of these insects. Among a variety of candidate compounds tested, two lectins, a fungal toxin, and one venom tested positive for activity against the putative whitefly symbionts, based on interference with honeydew production. Intact mycetomes isolated from surface-sterilized adult and nymph whiteflies and eggs converted sucrose to trehalulose, glucose, and fructose. Under these experimental conditions, trehalulose was produced only by fermentation of sucrose and raffinose.

B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diagnostics and resistance; virus-vector specificity and interactions.

Diseases of vegetable and ornamental crops incited by whitefly-transmitted geminiviruses, or Subgroup III of the Geminiviridae, were documented in Florida, Hawaii, and Yucatan, Mexico. One non-geminivirus, the tomato infectious chlorosis virus of tomato was described for the first time in California during 1994. The virus has

filamentous rod-shaped virions similar to those of well-characterized closteroviruses, and is transmitted by the greenhouse whitefly, *Trialeurodes vaporariorum* West., but not by the *B. tabaci* complex.

The efficacy of polyethylene sheets was evaluated as barriers to reduce the incidence of disease incited by tomato yellow leaf curl virus in Israel (TYLCV-Is). It was suggested that control was acheived by a synergism between actual barrier protection and some other component of the polyethylene sheets that affect whitefly behavior.

Virus-vector studies indicated that the Florida isolate of bean golden mosaic virus (BGMV-Fl) is transmitted efficiently by the B biotype of *B. tabaci* (also *B. argentifolii*), and once acquired can be transmitted for the life of the vector. Individuals of the B biotype (also *B. argentifolii*) was shown capable of acquiring and transmitting two unrelated geminiviruses of tomato from a mixed infection. That geminivirus DNA could be detected in individual whiteflies allowed acquisition access periods on infected plants was demonstrated using virus-specific primers and polymerase chain reaction.

A PCR technique was developed for detection and identification of WFT geminiviruses. PCR primers were designed to target and amplify the core region of the capsid protein gene, the most highly conserved gene among Subgroup III members of the Geminiviridae. DNA sequences were obtained from amplified viral DNA fragments and used to construct a coat protein database against which additional viral sequences can be compared. The coat protein gene sequence database will be useful for geminivirus identification and to investigate phylogenetic relationships, possibly at the species (quasispecies) and subspecies (virus strain) levels.

Reports of Research Progress
Section C. Chemical Control, Biorationals, and Pesticide Application Technology
Co-Chairs: John C. Palumbo and Phil Stansly

Investigator's Name(s): D.H. Akey[1], O.T. Chortyk[2], M.G. Stevenson[3], and T.J. Henneberry[1].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Nicotiana Gossei Extract Activity Against Silverleaf Whitefly in Small Plot Trials

Small plot trials (0.01 ac) with *Nicotiana gossei* were conducted at a site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. The extract was tested at 0.2% V/V at 30 gal/ac.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for *Nicotiana gossei* extract at 87% efficacy (defined as % reduction from the untreated control block). It was the most effective ovicide (repellency included in ovicide definition) of the 11 agents tested. The efficacy standard was the pyrethroid mixture, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lb AI/ac), which had an efficacy of 70%. The extract and the pyrethroid mixture were significantly different (P = 0.05) from the other compounds tested but not from each other.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for *Nicotiana gossei* extract at 95% efficacy. The extract was comparable to the efficacy (96%) of the insect growth regulator, buprofezin (0.25 lb AI/ac), which was the most effective treatment of the 11 compounds tested against SLWF immatures. The two pyrethroid combinations, fenpropathrin/acephate and bifenthrin (0.04 lb AI/ac)/fenoxycarb (0.25 lb AI/ac) gave 82 and 89% efficacy, respectively. Although higher in percent efficacies, the differences between both the extract and the buprofezin efficacies compared to the 2 pyrethroid mixtures were not statistically significant.

These trials indicate that *Nicotiana gossei* extract is a highly efficient biorational agent for control of the silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: April - October 1994.

Insecticide Rotation Against SLWF for IPM Programs in Cotton

Studies, at Maricopa Agricultural Center, University of Arizona, Maricopa, AZ used DPL5415 cotton. Ground application and furrow irrigation were used. Planting was solid for 101-103 rows/5 ac. Four-5 ac blocks were used, each a treatment rotation (ROT). ROTs were subdivided into 3 replicates by strip, with 5 subplots in each replicate for 15 total sampling plots/ROT. SLWF eggs and large immatures were counted by leaf samples. Beneficials were sampled by sweeps. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was use at 0.125% V/Vwith all foliar (liquid) treatments. For early season control, the 1st two 5-ac ROTs received aldicarb as a side-dress of 14 lb. On ROT I, pink bollworm (PBW) NOMATE pheromone (1.6 oz/ac) was used against PBW post pin-head square. On Rotation II, an application was made with thiodicarb (10 oz AI/ac) against PBW at post pin-head square. On ROT III, oxamyl (0.25 lb AI/ac) was applied 3 times for early season pest and PBW control. ROT IV, a control, used best agricultural practices for the season; usually weekly applications of fenpropathrin/acephate (0.2 lb AI/ac and 0.5 lb AI/ac). For mid-season control, SLWF action thresholds of 2-3 adults/plant or 3-4 large immatures/leaf were used. ROTs I, II, and III received 2 applications of potassium salts of fatty acids (2% V/V). ROT IV received a 4th application of oxamyl (0.25 lb AI/ac). Treatments in ROTs I-III tried to preserve beneficial populations. For late season control, amitraz (0.25 lb AI/ac) and endosulfan (1 lb AI/ac) was applied twice in 5 days in ROTs I-III. Pyrethroid as esfenvalerate was applied twice, 1st with endosulphan, 2nd with methomyl and chlorpyrifos. BT was applied against worm pests. In ROTS I-III, SLWF population were controlled, beneficials were not as numerous as expected, and yields were 2.3 bales/ac In ROT IV, SLWF populations were lowest (sig $P<0.05$), but some fenpropathrin resistance occured (ns at $P<0,05$), and yield was 3.4 bales/ac (sig. at $P<0.05$). The 3.4 bales/ac was higher than the 2.5 bales/ac (sig.$P<0.05$) yield by air application on the rest of the farm.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Azadirachtin (Azatin) and KDF-0520 (Agridyne Technologies Inc.) Activity Against Silverleaf Whitefly in Small Plot Trials

Small plot trials (0.01 ac) with azadirachtin and KDF-0520, biorational neem or neem-based pesticides were conducted at a site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. Azadirachtin and KDF-0520 were tested at 20 g AI/ac at 30 gal/ac. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed that neither were significantly different from the untreated control block (P = 0.05). KDF-0520 had 6% efficacy (defined as % reduction from the untreated control block) and azatin had 0% efficacy. In contrast, the most effective ovicide (repellency included in ovicide definition) of the 11 agents tested was a *Nicotiana gossei* extract at 87% efficacy. The efficacy standard was the pyrethroid mixture, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lb AI/ac), which had an efficacy of 70%.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for Azatin at 89% efficacy. It had the fourth highest activity of the agents tested against SLWF immatures. KDF-0520 had the lowest efficacy of 31%. The two pyrethroid combinations, fenpropathrin/acephate and bifenthrin (0.04 lb AI/ac)/fenoxycarb (0.25 lb AI/ac) gave 82 and 89% efficacy, respectively. The Azatin efficacy at 89% was not significantly different (P = 0.05) than that of the 2 pyrethroid mixtures.

These trials indicate that Azatin is an efficient biorational agent for control of immature silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Buprofezin Activity Against Silverleaf Whitefly in Small Plot Trials

Small plot trials (0.01ac) with the insect growth regulator, buprofezin (0.25 lb AI/ac) were conducted at a site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for buprofezin at a 61% efficacy (defined as % reduction from the untreated control block). Buprofezin was the third most effective ovicide of the 11 agents tested.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for buprofezin at a 96% efficacy. Buprofezin was the most effective treatment of the 11 agents tested against SLWF immatures. The two pyrethroid combinations, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lb AI/ac) and bifenthrin (0.04 lb AI/ac)/fenoxycarb (0.25 lb AI/ac) gave 82 and 89% efficacy, respectively. Although higher in percent efficacy, the differences between buprofezin efficacy and the 2 pyrethroid mixtures were not statistically significant.

These trials indicate that the insect growth regulator, buprofezin (a chitin inhibitor) is a highly efficient biorational agent for control of the silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Comparisons of Buprofezin Formulations Against Silverleaf Whitefly in Medium Plot Trials

Medium plot trials (0.1ac) with the insect growth regulator, buprofezin, were conducted at a site in Maricopa, AZ with 3 replicates per treatment in a test of 2 formulations (one liquid emulsion and one wettable powder) and two rates (0.25 and 0.038 lbs/ac) for SLWF control in a CRBD experiment.

Further, the liquid emulsion was formulated at 2 different sites designated as NN and NA. The wettable powder was formulated at the site designated as NA. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed significant control ($P = 0.05$) for buprofezin at a 61% efficacy (defined as % reduction from the untreated control block). Buprofezin was the third most effective ovicide of the 11 agents tested.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control ($P = 0.05$) for buprofezin at a 96% efficacy. Buprofezin was the most effective treatment of the 11 agents tested against SLWF immatures. The two pyrethroid combinations, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lb AI/ac) and bifenthrin (0.04 lb AI/ac)/fenoxycarb (0.25 lb AI/ac) gave 82 and 89% efficacy, respectively. Although higher in percent efficacy, the differences between buprofezin efficacy and the 2 pyrethroid mixtures were not statistically significant.

These trials indicate that the insect growth regulator, buprofezin (a chitin inhibitor) is a highly efficient biorational agent for control of the silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Interaction With Bifenthrin and Fenoxycarb for Chemical Control of Silverleaf Whitefly in Cotton

Small plot trials (0.01 ac) with the insect growth regulator, fenoxycarb (0.25 lb AI/ac) and the pyrethroid, bifenthrin (0.04 lb AI/ac) were conducted at site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for bifenthrin at a 56% efficacy (defined as % reduction from untreated control block), 0% efficacy for fenoxycarb alone, and a 50% efficacy for the mixture of bifenthrin and fenoxycarb (no significant interaction between bifenthrin and the fenoxycarb/bifenthrin mixture).

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for bifenthrin alone and for fenoxycarb alone at a 67% efficacy and an 89% efficacy for the mixture of bifenthrin and fenoxycarb. The 89% efficacy for the fenoxycarb/bifenthrin mixture was greater than the standard efficacy control which was a fenpropathrin (0.2 lb AI/ac /acephate (0.5 lb AI/ac) mixture which gave an 82% efficacy; these differences were not statistically significant at P = 0.05.

These trials indicate that fenoxycarb has potential value as a synergist for pyrethroids and should be investigated further for its synergistic actions with pyrethroids and other chemistries against silverleaf whitefly. The rate for bifenthrin is usually 0.1 lb AI/ac when used alone and 0.08 lb AI/ac when used in a combination mixture. Here, because we applied weekly, we used a low rate of only 0.04 lb AI/ac. The synergism by fenoxycarb with this rate of bifenthrin was encouraging. It is likely that a higher rate of bifenthrin would have had higher efficacies.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Pymetrozine (CGA 215'944, Ciba) Activity Against Silverleaf Whitefly in Small Plot Trials

Small plot trials (0.01 ac) with pymetrozine, pyridine azomethine, were conducted at a site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. Pymetrozine, believed to have a unique mode of action-that of feeding inhibition, was tested at 0.25 lb AI/ac at 30 gal/ac. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed significant control ($P = 0.05$) for pymetrozine at 42% efficacy (defined as % reduction from the untreated control block). It was the fifth in ranking as an ovicide (repellency included in ovicide definition) of the 11 agents tested. The efficacy standard was the pyrethroid mixture, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lbAI/ac), which had an efficacy of 70%; however the most effective ovicide was *Nicotiana gossei* extract with an efficacy of 87%. Although the efficacy of the pymetrozine treatment was significant as an ovicide, it was significantly less ($P = .05$) than that of the pyrethroid mixture.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control ($P = 0.05$) for pymetrozine at 80% efficacy. It was comparable to the efficacy standard (82%, $P = 0.05$), fenpropathrin/acephate.

These trials indicate that pymetrozine (CGA 215'944) is a potential agent for control of the silverleaf whitefly and that: 1) more dose response levels need to be field tested and 2) this agent should be tested in combination with another agent.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1994.

Pyriproxifen Activity Against Silverleaf Whitefly in Small Plot Trials

Small plot (0.01 ac) trials with pyriproxyfen (Valent/Sumitomo S-71639), a biorational pesticide that works as an insect growth regulator (juvenile hormone mimic), were conducted at a site in Maricopa, AZ with 5 replicates per treatment in a test of 11 candidate agents for SLWF control in a CRBD experiment. Pyriproxyfen was tested at 20 g AI/ac at 30 gal/ac. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V.

Data for mean egg numbers per square cm of leaf for the last two applications of five showed that pyriproxyfen treatments were not significantly different from the untreated control block (efficacy = 0%, P = 0.05). Efficacy was defined as % reduction from the untreated control block. In contrast, the most effective ovicide (repellency included in ovicide definition) of the 11 agents tested was a *Nicotiana gossei* extract at 87% efficacy. The efficacy standard was the pyrethroid mixture, fenpropathrin (0.2 lb AI/ac)/acephate (0.5 lbAI/ac), which had an efficacy of 70%.

Data for mean numbers of large immatures per square cm of leaf for the last two applications of five showed significant control (P = 0.05) for pyriproxyfen at 83% efficacy. It had the fifth highest activity of the agents tested against SLWF immatures. The efficacy standard, fenpropathrin/acephate gave 82% efficacy. The differences between pyriproxyfen and the efficacy standard were not significant.

These trials indicate that pyriproxyfen is an efficient biorational agent for control of immature silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September, 1992 and 1993.

Use of a 400 psi Hydraulic Sprayer for Ground Control of SPWF in Cotton

Applications were made with a 4-row spray boom with drops designed to spray the undersides of cotton leaves (see Akey et al., Proc.Beltwide Cotton Conferences 1992). The boom was attached by a 2-point hitch to a John Deere Hi-Cycle™ 600 sprayer. Spray trials were conducted for the 1994 SPWF season in upland cotton DPL 5415. Seven nozzles (TeeJet, Spray Systems Inc.) per row (at 3 positions per side on swivel-heads adjusted at various upward angles with an overhead nozzle directed downward) were used to obtain leaf coverage at rate of 30 gal/ac. The pressure used was 400 psi at the nozzles (425 psi at the pump, Model 390, 3 piston, 5 frame, Cat Pumps USA). The rate was obtained by using Cone Jet TX-SS2 (Spray Systems Inc.) in the spray heads. Additionally, mainline filters followed by screened 100 mesh check valve filters in the spray heads were used to keep the nozzles from clogging and to reduce drip after the boom was shut off.

Spray efficacy was determined by 1) efficacy of insecticides applied against SPWF large immatures as measured by percent reduction from untreated control blocks, 2) by leaf coverage of upper and lower surfaces of main leaves at positions from the terminal down as leaves 5, 7, and 9, as determined by dye as follows: field application with the sprayer of a solution of Leucophor EFR Liquid dye (Sandoz Chemical Corp.) and fluorescein dye (Sigma Chemical Co.) and then use of ultraviolet color photography of leaf samples 10-12 hr after sampling; and digitization by video to obtain percent coverage, droplet pattern, and size, and 3) true particle size as determined by microscopic examination. The nonionic wetter/spreader/penetrant adjuvant, Kinetic (Helena Chemical Company), was used at 0.125% V/V to aid adherence of all sprayed agents.

At 400 psi, microscopic examination showed a particle size range of 65 to 150 microns. No damage to flowering structures, bolls, nor foliage was observed by the 400 psi spray with this droplet size range. Also, the positioning of 6/7 of the spray in the cotton canopy itself, reduced drift to the point that spray operations were able to be conducted under higher wind conditions than usually acceptable for ground application.

About 4 acres of experimental plots ranging from 0.1 to 1.5ac in size were sprayed weekly throughout the season. Little damage to the cotton plants was observed. Although some bolls were pulled off of the plants, the number was acceptable (2-4/field length of 4 rows) compared to the benefit of spray that covered the undersides of the leaves. This was verified by the yield increased compared to spray techniques that did not give coverage of leaf undersides (1993 data).

A commercial application of ground spraying for season-long pest control may be feasible by use of a 24-row plant/skip 4-row planting scheme. This would allow spray equipment to enter fields requardless of irrigation schedules and meet "set aside" requirements for regulatory purposes. Our 1995 plans include trials with 12-row plant/skip 4 (some cases 2) with 5 nozzles per row. Some preliminary work may include 90 foot booms to try the 24/4 concept.

Investigator's Name(s): M.J. Ansolabehere, J.P. Chernicky, and S. West.

Affiliations & Locations: Valent USA Corporation, Fresno, CA; Arid Ag-Research, Inc., Maricopa, AZ; Research Designed For Agriculture, Yuma, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September, 1994.

SLWF Control in Cotton With Pyriproxyfen, an IGR

Pyriproxyfen (V-71639) is an insect growth regulator (IGR) which is being developed in the United States for control of silverleaf whitefly, Bemisia argentifolii (SLWF) in cotton. Pyriproxyfen acts as a juvenile hormone mimic and causes inhibition of metamorphosis, embryogenesis, reproduction, and larval development in certain insects. In SLWF, pyriproxyfen inhibits egg hatch, either through the females or by direct contact, and suppresses adult emergence when larvae stages are affected. Pyriproxyfen also exhibits pronounced translaminar movement in cotton leaves which also inhibits egg hatch.

In 1994, pyriproxyfen was tested by numerous University, USDA, and private contract personnel to determine its effectiveness on SLWF in AZ and CA. In general, pyriproxyfen provided effective SLWF control and demonstrated IGR tendencies by reducing nymphal populations of the SLWF while not affecting adult populations and producing mixed results on egg populations. This paper will report on two separate trials that were conducted by private contract personnel in 1994.

A trial in Yuma, AZ (Research Designed for Agriculture) was replicated 3 times with each replicate consisting of 8 - 40" rows X 165 ft (approximately 0.1 acre per replicate). Applications were in 20 gpa at 45 psi pressure with overhead and drop nozzles. Pyriproxyfen at 20 g ai/acre was applied as a single application on 7/7/94 and as a double application on 7/7 and 7/29/94. Comparison was made to an untreated control and a Danitol + Orthene (0.2 +0.5 lb ai/acre) standard treatment which was applied on 7/7 and 7/29/94. On 8/16/94 (40 days after treatment) the single pyriproxyfen application was significantly reducing SLWF nymphs 66% below the untreated control. On this same date (18 days after the second application), the double pyriproxyfen application was significantly reducing SLWF nymphs 82% below the untreated control and the double Danitol + Orthene application was significantly reducing SLWF nymphs 84% below the untreated control. Neither of the pyriproxyfen regimes significantly reduced SLWF adult or egg populations on this rating date.

A trial in Maricopa, AZ (Arid Ag-Research, Inc.) was not replicated and consisted of cotton blocks of 24 - 40" rows X 280 ft (approximately 0.5 acre) in which 4 sub-samples were taken to determine efficacy. Applications were in 20 gpa at 80 psi pressure with overhead and drop nozzles. In one block, pyriproxyfen at 20 g ai/acre was applied as a double application on 7/12 and 8/2/94; in another block, pyriproxyfen at this same schedule was alternated with Danitol + Orthene (0.2 +0.5 lb ai/acre) on 7/22/94. Also included in the trial were blocks that consisted of standard grower treatments and an untreated control. In this trial both pyriproxyfen regimes and the grower standard were significantly reducing nymph and egg populations on 8/27/94 (25 days after the last application). Pyriproxyfen, alone, was significantly reducing nymph populations by 93% and egg populations by 87% below the untreated control on this date. Pyriproxyfen, alone, did not significantly reduce adult populations in this trial.

Results from these two trials indicate that pyriproxyfen has activity on SLWF and as an IGR does not reduce all life stages of the pest and will probably fit well in an integrated pest management program with other types of insecticides. The decrease in egg population observed in the larger scale unreplicated trial indicate that larger plot areas may be needed to determine the total effects produced by IGRs such as pyriproxyfen.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

Molecular Analysis of Cyclodiene Resistance Associated Mutations Among Populations of the Sweetpotato Whitefly *Bemisia tabaci*

Two PCR-based molecular diagnostics were used to investigate whether cyclodiene resistance is uniquely associated with the novel B biotype of the sweetpotato whitefly *Bemisia tabaci* (Gennadius) and thus establish whether resistance could have acted as a driving force in the recent and rapid spread of this biotype. Previous studies have shown that a single point mutation coding for an alanine to serine replacement in the *Drosophila Rdl* gene confers high levels of resistance to cyclodiene insecticides. Following identification of an analogous point mutation in the *B. tabaci Rdl* homologue, PCR amplification of specific alleles (PASA) demonstrated that the corresponding alanine to serine replacement is not confined to the B biotype but is also present in indigenous whitefly populations found on crop plants. Single stranded conformational polymorphism (SSCP) analysis of the same region of the *Rdl* gene was used to confirm whitefly genotype and examine the degree of nucleotide polymorphism among whitefly strains. A comparison of SSCP banding patterns revealed a remarkable lack of nucleotide variation among strains conforming to the B biotype whereas several of the non-B strains exhibited different banding patterns. Sequence analysis of these strains revealed one or more nucleotide polymorphisms including a novel resistance associated mutation in one collection from the Sudan. These results show that cyclodiene resistance is not uniquely associated with the B biotype. However, the lack of genetic variability in the *Rdl* gene among B strains is consistent with the recent origin and spread of this novel biotype.

Investigator's Name(s): L.L. Beehler[1], N.C. Toscano[1], and W. Coates[2].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January - December 1993

Evaluation of Insecticide Application Equipment for Spray Deposition and Efficacy Against *Bemisia argentifolii* on Tomatoes

Five sprayer types applying insecticidal soap and *Bacillus thuringiensis* to tomatoes were compared for spray deposition and efficacy against *Bemisia argentifolii* (silverleaf whitefly) and lepidopterous pests including *Spodoptera exigua* and *Heliothis* species.

Sprayers used were the Degania, a high output (54 GPA) sprayer using an inflatable boom, a Controlled Droplet Applicator using a spinning disk and oscillating fans to distribute a very low volume of spray (1.8 GPA) and an electrostatic sprayer which electrically charges the droplets and expels them with an air blast. The electrostatic sprayer was tested with the charge on and off applying 12 GPA in both cases. A standard conventional type sprayer was also included in the test, which used 3 twin-jet type nozzles per row and had an output of 60 GPA.

Spray deposition was measured using computer scanned water sensitive papers which were attached to the tomato leaves near the top of the plant, and ultraviolet photography of fluorescent dye applied through the sprayers directly onto the leaves. In addition, a spectraphotometric assessment of a food dye which was washed off the leaf, provided information on the concentration of material applied to both dorsal and ventral sides of the leaf.

There was no significant difference between the sprayers with respect to percent coverage assessed by the water sensitive papers for either the dorsal or ventral surfaces. When spray deposition was measured by the more sensitive leaf washing method, the Degania and Controlled Droplet Applicator had significantly less coverage to the dorsal surfaces than the other sprayers tested, but deposition was not significantly different on the ventral surfaces.

Investigator's Name(s): J.B. Carlton.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

Retention Phenomenon of Agricultural Liquid Formulations on Plant Leaves

A simple handheld field tool called, an immersion cell, was designed and developed to pursue studies of liquid formulation retention effect on plant leaves. The immersion protocol is one in which a finite leaf disk area is covered with a measured volume of a liquid formulation. A decanting process removes that liquid that is classed as runoff. By measuring the runoff volume and comparing it to the original, the maximum liquid retention is obtained. Field studies were carried out to provide data for quantitative analysis. Four types of plants and three different liquid formulations were subjected to the immersion-retention study. Statistical analysis revealed a wide variety of repeatable retention phenomena. The analysis permitted a comparison of retention among the four type plants subjected to the three formulations, and separately for both sides of the leaves. Tap water was found to have the highest retention potential ((L/cm2) among the formulations on plant species/types studied. This was true for both the tops and bottoms of all type plant leaves. This research provides a technique/protocol for making a basic measurement regarding the retention forces that interface a liquid formulation with a plant leaf surface. It will have academic and practical value especially since it can be readily measured from plant leaves in the field environment using virtually any liquid formulation. In any specific spray application, however, it will be necessary to establish either a correlation or a relationship with the maximum retention data.

Investigator's Name(s): J.B. Carlton, L.F. Bouse, and I.W. Kirk.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

Electrostatic Charging of Aerial Spray Over Cotton

Electrostatically charged aerial spray studies were carried out over cotton fields. The study was planned and structured to obtain needed engineering information regarding the role and domain of applicability of this technology/methodology for aerial application. Spray deposition measured directly from the top and bottom of cotton leaves was used to quantitatively evaluate three charging protocols; (1) bipolar, (2) alternating polarity, and (3) no-charge. The bipolar spray charging protocol gave significantly higher deposits on the cotton leaves than the no-charge or alternating polarity protocol. Mean deposit levels were 4.3 times higher with bipolar charged spray compared to no-charge spray. Bipolar charging also showed a 3.0-fold increase in deposit over the alternating polarity protocol. Bipolar charging was also demonstrated to be effective in increasing plant canopy penetration and exhibiting a leaf wrap-around effect. As expected; deposit means were greater on the tops as opposed to the bottoms of the leaves, upper canopy deposits were greater on the tops as opposed to the bottoms of the leaves, and upper canopy deposits were greater than lower canopy deposits. The experiments also showed a significant replication effect which may have been related to a low field/plant moisture content resulting from the irrigation schedule. The large scale electric field effects, associated with bipolar charging presents information for much further thought and study.

Investigator's Name(s): Richard B. Chalfant and Harold R. Sumner.

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Research & Implementation Area: Entomology, Agricultural Engineering.

Dates Covered by the Report: January 1 to December 31, 1994.

Surface Application Equipment and New Pesticides to Control the Silverleaf Whitefly and Silverleaf on Summer Squash in Georgia

Experiment 1: Performances of three sprayers were tested on squash to control the silverleaf whitefly and to reduce expression of silverleaf using 0.5 & 1.0 lb (AI)/acre of endosulfan, with and without addition of 2% Saf-T-Side oil. Cv 'Gold Slice' summer squash was planted 31 August, 1994. Sprayers were a Berthoud tm air boom delivering 30 gpa with two air shear nozzles per row, an electrostatic air assist sprayer by Electrostatic Spraying Systems delivering 4 gpa, and a hydraulic boom equipped with three TX18 hollowcone nozzles and delivering 50 gpa at 50 psi. Plots were three 2-row beds, 18 ft wide X 45 ft in length. Experimental design was a randomized complete block with 4 replications. Application dates were 14, 19 and 26 September. Treatments were evaluated by recording numbers of silvered plants, adults, eggs and nymphs. Data were analyzed according to ANOVA and the Waller-Duncan K-Ratio T test for mean separation.

There were significant differences in silverleaf counts. When averaged across all rates and formulations, plots treated with the air boom sprayer had the least silvering. The air boom sprayer showed the greatest response to dose and there was a marked reduction in silver leaf with the addition of oil. Specifically, lowest silvering was in plots treated with the air boom sprayer using 0.5 and 1.0 lb (AI)/acre of endosulfan plus oil. The electrostatic and hydraulic sprayers produced results similar to each other and showed no improvement with the addition of oil. There were significant treatment differences in adult and nymph counts. Adding oil reduced numbers of nymphs with all three sprayers. The data indicate that the air boom sprayer was superior to the electrostatic and hydraulic sprayers under the test conditions. In 1992 when these sprayers were compared under similar conditions the air boom sprayer did not perform as well as the hydraulic but did show a positive response to the addition of oil.

Experiment 2: Experimental insecticides were evaluated to control the silverleaf whitefly on summer squash planted on 4 August, 1994. Plots were two rows, 6 ft wide X 50 ft in length and treatments were replicated 4 times in randomized complete blocks. Insecticides were sprayed with a tractor mounted 2-row boom sprayer equipped with TX18 hollow cone nozzles per row. Pressure was 100 psi and spray volume was 50 gal of water per acre. Spray dates were 15, 19 & 25 August, and 1 September. NTN33893 (Miles, Inc.) drenches were applied to the planted furrow on 5 August in 100 gallons water per acre. Insecticidal efficacy was determined by recording adult whiteflies on 5 leaves per plot, counting eggs and nymphs in three 1 cm^2 fields on 5 leaves per plot, and recording percent of plants showing silvering. Yields were taken twice from 10 linear ft of plot. Data were analyzed according to ANOVA and the Waller-Duncan K-Ratio T test for mean separation.

Lowest numbers of adults and eggs were in plots treated with 1.0 lb [AI]/acre of endosulfan and the tankmix of 0.2 lb [AI]/acre of CGA215944 + 0.25 lb [AI]/acre of fenoxycarb. There were no significant differences in nymph counts. The most reliable measure of insecticidal performance against the whitefly on summer squash is prevention of silvering which is a reaction of the leaf to the feeding of nymphs. Almost complete control was obtained with tankmixes of 0.2 lb [AI]/acre of CGA215944 + 0.25 lb [AI]/acre of fenoxycarb and 0.25 lb [AI]/acre of buprofezin + 1.0 lb [AI]/acre of endosulfan. All treatments produced yield significantly higher than the untreated check. Highest yield was with the tankmix of 0.2 lb [AI]/acre of CGA215944 + 0.25 lb [AI]/acre of fenoxycarb.

Investigator's Name(s): C.C. Chu, T.J. Henneberry, H.H. Perkins, B.E. Mackey, N. Prabhaker, S.E. Naranjo, and D.H. Akey.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993-1994.

Control Action Thresholds for Silverleaf Whitefly for Cotton Yields and Lint Quality

Silverleaf whitefly, *Bemisia argentifolii* Perring & Bellows, has been a devastating pest of cotton (*Gossypium* spp.) in the south and southwestern United States since 1991. Action thresholds in relation to cotton yields and quality losses are urgently needed as components of integrated management systems for whiteflies. Studies with cotton insecticide treatments initiated each week from shortly after cotton seedling emergence to late in the cotton season were conducted at the Irrigated Desert Research Station, Brawley, CA in 1993 and 1994. The results showed that the best action thresholds in relating to cotton yield was 0.31 nymphs/cm^2 of leaf disc sampled from 5th main stem node leaves in control and insecticide treated plots. For adult whiteflies, the action threshold was found to be 4.16 adults/leaf. Our best estimate of the light cotton lint stickiness was 0.35 nymphs/cm^2 leaf disc and 4.29 adults/leaf. Analyses of action thresholds to incorporate economic consideration are in progress.

Investigator's Name(s): C.C. Chu, T.J. Henneberry, H.H. Perkins, S.E. Naranjo, N. Prabhaker, D.H. Akey, and B.E. Mackey.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 - 1994.

Relationships Between Silverleaf Whitefly Populations and Sticky Cotton

Studies to determine the relationship between silverleaf whitefly, *Bemisia argentifolii* Perring & Bellows, populations and sticky cotton (*Gossypium hirsutum* L.) were conducted in the Imperial Valley, CA, in 1993 and 1994. The insecticide mixture of fenpropathrin (Danitol® 2.4EC, α-Cyano-3-phenoxybenzyl 2,2,3,3,-tetramethylcyclopropanecaboxylate) and acephate (Orthene®, O,S-Dimethyl acetylphosphoramido-thioate) was used to establish more than ten levels on silver whitefly populations in cotton each year. Applications of the pesticide mixture were initiated each week in a series of plots beginning from immediately after cotton emergence, when whitefly populations were very low, until late in the cotton season in August, when whitefly populations were extremely high. The resulting whitefly populations in cotton plots treated with different numbers of applications and lint stickiness were fitted into a regression analysis. The analyses showed that lint stickiness was a quadratic function of whitefly nymphs/cm^2 of leaf area and adults/leaf. Each regression accounted for 90% or more of the insect population variations. We also found that percent sugars and lint stickiness as indicated by thermodetector readings were highly linearly correlated.

Investigator's Name(s): Peter Ellsworth and Donna Meade.

Affiliations & Locations: University of Arizona-Maricopa Agricultural Center, Maricopa, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

Field Evaluation of Novel Chemistries for Control of the Sweetpotato Whitefly

Insecticides of novel chemistry were evaluated for their ability to control the sweetpotato whitefly (SPWF), Bemisia tabaci (Genn.) [strain B = *B. argentifolii* (Bellows & Perring)] and their selectivity; specifically their impact on beneficial species. The test compared five experimental products to Danitol® + Orthene®, Ovasyn®, a Phaser®/Capture® rotation, and an untreated check. The rotational treatment consisted of weekly alternation of Phaser alone (0.75 lb ai/A) with a Phaser (1.0 lb ai/A) plus Capture (0.02 lb ai/A) treatment. Four of the experimental products were insect growth regulators (IGR's), V71639, fenoxycarb, C215944, and buprofezin. Buprofezin was used in three formulations and at two rates of a single formulation. One other experimental compound tested, NTN 33893; has complex modes of action including antifeedant activity. All insect stages, adults and immatures, were monitored weekly by leaf turns and leaf samples. All products were significantly more effective in reducing most SPWF life stages than the untreated check yet most were moderate in their overall impact on populations. Data on yields were also taken, these were not significantly effected by treatment. Information about impact on beneficials is in development.

Investigator's Name(s): Peter Ellsworth and Donna Meade.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

The Effects of Carbamates on Sweetpotato Whitefly Population

Carbamates, were the primary focus of this year's study. Selected carbamates, (Vydate-CLV®, and Lannate®), were tank-mixed with either a pyrethroid or an organophosphate partner and evaluated against, an untreated check, Danitol® plus Orthene®, and endosulfan plus Ovasyn®. Non-pyrethroid applications began two weeks earlier than the pyrethroid containing treatments. The later experimental treatments began at 11 adult SPWFs/leaf while the former were initiated earlier at 2.5 adult SPWFs/leaf. Non-pyrethroid plots were sprayed six times in total, while the pyrethroid plots were sprayed only four times. Efficacy was evaluated using three sampling methods: leaf turns for adult counts, microscopic leaf counts for immature stages, and sweeps for other arthropod fauna. Of the non-pyrethroids treatments, most were moderate in their effects against all SPWF stages, yet Phaser® + Ovasyn was the most consistently effective combination. With the pyrethroid containing treatments all combinations of Danitol were equivalent in their effectiveness upon all SPWF stages.

Investigator's Name(s): Hollis M. Flint.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1 January - 31 December 1994.

Garlic Oil for Whitefly Control on Cotton

Garlic oil was tested as a repellent for whiteflies infesting cotton. Garlic is available in a wide range of products found in supermarkets, pharmacies, and insecticidal products. We tested garlic extract made from commercial chopped garlic obtained from the supermarket and later commercial garlic oil. The latter oil is derived from crushed garlic cloves and is highly irritating (requires handling in a fume hood using gloves, goggles, and a breathing apparatus). Garlic oil is highly volatile and is comprised of some 20 compounds and requires emulsifiers for the aqueous formulations we used. Sprays were applied using compressed air hand sprayers at 40 psi.

Sprays made from chopped garlic were repellent to whiteflies on the undersides of leaves for up to 5 days. New leaves were readily attacked indicating no systemic action. Counts of eggs and nymphs indicated infestations were reduced about 80%. There were no phytotoxic effects. We noted that the chopped garlic product was supplied in soybean oil and subsequent tests of soybean oil only at 2-4% duplicated the above results. Sprays of up to 2% commercial garlic oil provided reductions in eggs and nymphs comparable to 2% soybean oil while combining the two did not improve results. Phytotoxicity occurred above 2% and occasionally at this percentage. Commercially available insect control products containing garlic oil alone or in combination with other materials gave no better control than 2-4% soybean oil. We concluded that garlic oil is highly volatile and provides little protection for cotton after 3-4 days.

Investigator's Name(s): Stefan T. Jaronski, Pauline Wood, and Nancy Underwood.

Affiliations & Locations: Mycotech Corporation, Butte, MT.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: May - July 1994.

Assessment of *Beauveria Bassiana* Mycotech BB401 and *Paecilomyces Fumosoroseus* Mycotech PFR612 Efficacy Against Silverleaf Whitefly in Imperial Valley, California

As part of the joint USDA/ARS - Mycotech Corp. cooperative program to develop fungi as biocontrol agents of *Bemisia* spp., conidial powders of *Paecilomyces fumosoroseus* Mycotech Strain PFR612 and *Beauveria bassiana* Strain 401 were applied to small plots in late-season commercial spring canteloupe (var. 'Topscore'). Rates of fungus were 1×10^{13} and 2×10^{13} conidia per acre applied in 50 GPA water with nonionic surfactant; untreated and carrier controls were also included. Four applications at 4-day intervals were made beginning May 6, approximately three weeks before first harvest. Applications were made with backpack air blast equipment. SLWF nymphal counts in the untreated and carrier control plots increased from 1.8-2.2 to 9-10 per cm^2 during the 18 days of the trial. The fungi yielded 81-87% control of large and red-eyed nymphs; control was 63-69% when crawlers and small nymphs were included in the analyses. There were no significant differences in efficacy between the two fungi nor between the two rates (Tukey's HSD, $p = .05$).

Additional field trials of the two fungi were conducted in Deltapine 5415 cotton at the USDA/ARS Irrigated Desert Research Station. *B. bassiana* Strain BB401 and *P. fumosoroseus* Strain PFR612 were applied at 2×10^{13} conidia per acre in 20 GPA water with a nonionic carrier. (A carrier control was also included in the trial.) Five applications were made at 4-6 day intervals, beginning June 16, at which time the cotton was 16 nodes high and flowering, and SLWF populations were 4-21 nymphs per cm^2. Materials were applied with backpack air blast equipment. The density of the cotton canopy reduced the amount and regularity of spray coverage, as indicated by analyses of spore counts on lower leaf surfaces. Nevertheless, twenty days into the test, the two fungi gave 63-78% reduction of nymphal numbers compared to the carrier control. At 26 days, when the trial was terminated control was 48-53%. There were no significant differences in the efficacies of the two fungi. Extremely high mid-canopy air temperatures (greater than 35°C., the normal, laboratory upper temperature limit for these fungi) for at least four hours each day during the test may have negatively impacted fungal efficacy.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July 1, 1994 - September 30, 1994.

Response of Silverleaf Whitefly to Spray Droplet Characteristics of Danitol Plus Orthene on Cotton

Spray mixtures of Danitol 2.4E + Orthene 90S at 0.20 + 0.50 and Capture 2E + Orthene 90S at 0.08 + 0.50 lb active ingredients per acre, were applied in a spray table to potted cotton plants infested with immature stages of a greenhouse strain of whitefly, *Bemisia argentifolii*. The spray mixtures were applied at 3 and 5 gallons per acre using two flat fan nozzles, 650017 and 8002E. Sprays were made simultaneously both on the top and bottom surfaces of cotton leaves. The 650017 nozzle produced small droplets with a volume median diameter ($D_{V0.5}$) value equivalent to 157 µm while the 8002E nozzle produced large droplets with a $D_{V0.5}$ value equivalent to 308.5 µm. The droplet density (number of droplets per cm^2) produced by the 650017 and 8002E nozzles averaged 190 and 48, respectively. The mean percentage of spray volume containing droplets <200 µm delivered by the 650017 and 8002E nozzles averaged 82 and 8%, respectively. These values were significantly different ($P < 0.05$).

When sprayed on bottom surface of the leaves, the percentage mortality of small and large nymphs averaged 55.6 and 32.5%, respectively. When sprayed on top surface of the leaves, the percentage mortality of small and large nymphs averaged 28 and 5.8%, respectively. The analysis of variance of mortality data showed that droplet size and droplet density of spray plumes examined in this study did not significantly influence whitefly mortality.

Glass vial tests conducted with Danitol + Orthene at 1:2.5 ratio, respectively, showed that whitefly adults used in this study have LC_{50} value equivalent to 35 µg per vial. Danitol and Orthene showed poor toxicity and nonsignificant regressions when tested alone. Adults of Weslaco greenhouse strain when exposed to Danitol + Orthene at 1:1 ratio showed LC_{50} value of 0.031 µg per vial; Orthene alone showed LC_{50} value of 46.18 µg per vial and Danitol alone had nonsignificant regression.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 8 July - 5 August 1994.

The Effectiveness of Mist Blower in Reducing Whitefly Numbers

Mist blower was used to treat 5, 10, or 15 rows along edge of cotton fields with 12 replicates of each treatment. Whitefly, adults, eggs, and nymphs were counted on rows 1, 10, 20, and 30 and sticky yellow cards were placed at edge of field or in 1st middle. The whitefly samples on first row at field edges had the greatest reduction in whitefly numbers due to mist blower treatments, but the overall means did not show any difference among the three treatments. The distance of samples into the fields was the only parameter with significant differences. There were a few cases when the south or west side of the fields had numerically greater reduction in whitefly numbers, but none were significant. A one-way ANOVA of all data for row 10 samples indicated that plots with 15 rows treated had significantly greater reduction in whitefly, adult and nymph, numbers than plots that had 5 rows treated. This difference was found at row 10 only. There were no reductions in whitefly numbers at sample rows 20 and 30 which indicates that mist blower treatments did not have an extended effect into the cotton fields beyond the rows actually treated. Treating only 5 rows would results in a 67% savings in insecticide and a substantial saving in time required to treat the field edges. Overall there were significant differences in whitefly leaf counts on cotton leaves collected in treated and untreated plots, but no differences in sticky yellow card counts between treated and untreated plots.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: Research conducted from February - July 1994.

Monitoring for Resistance to Insecticides in Whitefly Populations from the Yaqui Valley, Sonora, Mexico

The silverleaf whitefly (SLWF) *Bemisia argentifolii* Bellows & Perring, n. sp., has become one of the most important insect pests in northwestern Mexico. In 1994 this insect reached very high populations in different crops grown in the Yaqui valley of Sonora. Damage was more serious in soybeans. Since insecticides are usually used as a primary control strategy for this insect in different crops, it is mandatory to have data on the susceptibility of the SLWF populations to the insecticides commonly used in the area. This information is needed in order to implement a resistance management strategy.

Glass vial bioassays were conducted to obtain base line mortality data on adult SLWF populations from different crops during 1994. The LC_{50} values obtained in March for populations collected from potato were as follows: Cypermethrin 25 μg/vial, endosulfan 195 μg/vial, methamidophos 571 μg/vial and methyl parathion 579 μg/vial. Data obtained in the same crop during April were as follows: Cypermethrin 4.4 μg/vial, endosulfan 86 μg/vial, methamidophos 172 μg/vial and methyl parathion 117 μg/vial. The LC_{50} values for populations collected from cotton in July were: Cypermethrin 26 μg/vial, endosulfan 73 μg/vial, methamidophos 193 μg/vial and methyl parathion 147 μg/vial. Results from populations collected from soybeans in July showed LC_{50} values as follows: Cypermethrin 43 μg/vial, endosulfan 84 μg/vial, methamidophos 99 μg/vial and methyl parathion 112 μg/vial. These values will be considered as base line data for further comparison of susceptibility for SLWF populations from the Yaqui valley to insecticides.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March 1994 through September 1994.

Cotton Insecticides Efficacy for Control of Silverleaf Whitefly

Cotton plots of 8 beds of 40 inch centers by 45 feet were sown March 16, 1994. The insecticide treatments included: Phaser® 3EC .75 lb (ai)/a, Phaser® 3EC .75 lb (ai)/a + Scout® X-TRA .02 lb (ai)/a, Scout® X-TRA .02 lb (ai)/a, Scout® X-TRA .02 lb (ai)/a + Ovasyn® 1.5EC .13 lb (ai)/a, Scout® X-TRA .02 lb (ai)/a + Orthene® 90S .5 lb (ai)/a, Mustang® 1.5EW .05 lb (ai)/a + Orthene® 90S .5 lb (ai)/a, Mustang® 1.5EW .05 lb (ai)/a + Thiodan® 3EC .75 lb (ai)/a, Capture® 2EC .1 lb (ai)/a + Orthene® 90S .5 lb (ai)/a, Capture® 2EC .05 lb (ai)/a + Vydate® CLV .5 lb (ai)/a, Capture® 2EC .05 lb (ai)/a + Lannate® LV .5 lb (ai)/a, Danitol® 2.4EC .2 lb (ai)/a + Orthene® 90S .5 lb (ai)/a, Danitol® 2.4EC .2 lb (ai)/a + Vydate® CLV .5 lb (ai)/a, and Danitol® 2.4EC .2 lb (ai)/a + Lannate® LV .5 lb (ai)/a. Insecticides were applied on June 3, then weekly June 14 through August 2, 1994, using a John Deere Hicycle 600 tractor with a 4 row spray boom, delivering 20 gpa at 100 psi.

The 5th position leaf below the terminus was extracted from 5 randomly selected plants per plot. Two leaf discs of 1.25 cm^2 were examined from the lower quadrants on each leaf using a binocular dissecting microscope and numbers of 1st through 4th instar nymphs were recorded. Adults from 5 plants at random in each plot were dislodged by twice beating the terminal portion into a 9" diameter circular black pan coated with a fine film of vegetable oil. Data from whitefly samples were recorded weekly from June 6 through August 15, 1994. Yield data were recorded as pounds of seed cotton per plot harvested August 31, with a commercial picker.

Efficacy differences among treatment means for adults and nymphs were very similar. The adult means were highly correlated with nymph means, r^2=0.89. The pyrethroid insecticides (Capture® 2EC, Danitol® 2.4EC, Mustang® 1.5EW, and Scout® X-TRA) all were efficacious when mixed with Orthene® 90S. Capture® 2EC and Danitol® 2.4EC were also efficacious mixed with Vydate® CLV, but less efficacious mixed with Lannate® LV. Mixtures with endosulfan, Phaser® 3EC and Thiodan® 3EC, or with Ovasyn® 1.5EC, do increase the efficacy of pyrethroids, but did not respond as well in this experiment. Scout® X-TRA used alone did not adequately control the silverleaf whitefly infestation on cotton in this experiment. There was a negative response in lint production correlated with the level of whitefly infestation; silverleaf whitefly adults with yield (r^2=0.76) and nymphs with yield (r^2=0.68).

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: February 1994 through June 1994.

Efficacy Evaluations of Insecticides for Control of Silverleaf Whitefly on Cantaloupe Melon

Cantaloupe melon (variety Topmark) plots of 2 beds of 80 inch centers by 50 feet were sown February 2, and replanted March 3, 1994. The experimental design was randomized complete block with four replications of an untreated control and 12 insecticide treatments including Admire 2 F injected one inch below the seed line at rates of 0.25 lb (ai)/a and 0.38 lb (ai)/a on February 2. Foliar spray treatments of Baythroid 2 EC at 0.05 lb (ai)/a + Monitor 4 at 0.5 lb (ai)/a were applied to the Admire 2 F 0.25 lb (ai)/a plots. The other foliar treatments were Danitol 2.4 EC at 0.2 lb (ai)/a + Orthene 75 S at 0.5 lb (ai)/a, Danitol 2.4 EC at 0.2 lb (ai)/a + Vydate L at 0.5 lb (ai)/a, Capture 2 EC at 0.08 lb (ai)/a + Thiodan 3 EC at 0.5 lb (ai)/a, Capture 2 EC at 0.08 lb (ai)/a + Vydate L at 0.5 lb (ai)/a, Capture 2 EC at 0.08 lb (ai)/a + Lannate LV at 0.5 lb (ai)/a, S-71639 0.83 EC (pyriproxyfen) at 0.04 and at 0.07 lb (ai)/a, Fenoxycarb 25 W at 0.31 lb (ai)/a + Sylgard 309 at 4 fl oz /100 gal, Fenoxycarb 25 W at 0.31 without Sylgard 309, and Fenoxycarb 25 W at 0.31 lb (ai)/a + Sterling 50 W at 0.44 lb (ai)/a. Foliar insecticide treatments were applied weekly from April 15 through June 1, using a tractor with a 2 row spray boom and 3 Albuz lilac nozzles/row, delivering 14.3 gpa at 80 psi.

The one leaf was extracted from 5 randomly selected plants per plot. Two leaf discs of 1.25 cm^2 were examined from the lower quadrants on each leaf using a binocular dissecting microscope and numbers of 1st through 4th instar nymphs were recorded. Data from whitefly samples were recorded weekly from April 12 through June 7, 1994. Yield data were recorded as numbers of fruit by size categories corresponding to the numbers that fit into a carton, pounds of fruit for each size category, and total numbers and pounds of fruit for an area of 0.04 acres from each plot on June 17, 1994.

Efficacy differences among treatment means for nymphs varied with the treatments and yields from the plots were correlated to the numbers of nymphs. The Admire treatments were in the soil for one month prior to replanting, but did provide control of silverleaf whitefly. The Admire treatment followed by Baythroid + Monitor had the greatest mean yield of 42.8 fruit and the second greatest yield of 84.7 pounds of fruit as compared to Danitol + Orthene which yielded a mean of 42.5 fruit weighing 87.1 pounds. Capture + Thiodan had a mean yield of 40.3 fruit weighing 83.5 pounds, followed by Sterling + Fenoxycarb with 34.5 fruit weighing 70.4 pounds, Capture + Vydate with 34.0 fruit weighing 69.2 pounds, and S-71639 at 0.07 lb (ai)/a with 32.3 fruit weighing 67.2 pounds. The above mentioned treatment means were not significantly, $P = 0.05$, from each other, but all were significantly greater than the untreated control which did not produce any marketable fruit. The yield for S-71639 at 0.04 lb (ai)/a and Capture + Lannate were 54.6 and 41.5 pounds, respectively, which was significantly greater than the control, but significantly less than Danitol + Orthene, Capture + Thiodan, and Admire followed by Baythroid + Monitor. The Danitol + Vydate treatment mean yield of 32.4 pounds was significantly greater than the control, but significantly less than all of the previously mentioned means except S-71639 at 0.04 lb (ai)/a and Capture + Lannate. Admire alone produced a mean of only 14 pounds of fruit, Fenoxycarb alone had a mean of 1.2 pounds and Fenoxycarb + Sylgard 309 had a mean of only 0.7 pounds of fruit, none of these treatments were significantly greater than the untreated control.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1993 through January 1994.

Evaluation of Insecticides for Control of Silverleaf Whitefly on Iceberg Lettuce

Several soil applied systemic insecticides and foliar insecticides were evaluated for efficacy against the silverleaf whitefly, *Bemisia argentifolii* (Bellows & Perring), on iceberg lettuce (CV."Empire"), Planted September 23, 1993. Pre-Plant treatments of Payload® 15G at rates of 0.75 & 1.0 lb (ai)/acre, DiSyston® 15G at 1.0 lb (ai)/acre, Admire® 240 FS at 0.16 & 0.31 lb (ai)/acre, and the CIBA experimental compound CGA215944 (Sterling® 50W) at 0.01 gm (ai)/meter were injected one inch below the seed line September 22. The CGA215944 treatment also received foliar sprays of fenoxycarb 25WP at 0.12 lb (ai)/acre applied three times in combination with CGA215944 as a foliar spray at 0.1 lb (ai)/acre three times at weekly intervals and then two applications of CGA215944 at 0.25 lb (ai)/acre alone as a foliar spray, at weekly intervals. Foliar spray treatments included Lorsban® 50W at 1.0 lb (ai)/acre, Lorsban® 50W + Capture® 2EC at 1.0 and 0.06 lb (ai)/acre, and Capture® 2EC + Monitor® 4 at 0.06 and 1.0 lb (ai)/acre applied weekly from October 8 to November 3.

Payload® 15G, DiSyston® 15G, and Lorsban® 50W treatments failed to control silverleaf whitefly and were not significantly ($P = 0.05$) different from the untreated control. Admire® 240 FS injected as a liquid provided season long control of silverleaf whitefly at both the 0.16 and 0.31 lb (ai)/acre rates. The Treatment with CGA215944 injected as a liquid and later sprayed with fenoxycarb and CGA215944 also provided a high level of control through the season as did the treatments with Lorsban® 50W + Capture® 2E and Capture® 2EC + Monitor® 4.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1993 through January 1994.

Evaluation of Insecticides for Control of Silverleaf Whitefly on Transplanted Cauliflower

Several foliar insecticides and soil applied insecticide treatments were evaluated for efficacy against the silverleaf whitefly, *Bemisia argentifolii.* The foliar insecticides were applied by ground using a tractor mounted sprayer applying 50 gpa at 425 psi using three nozzles per seedline. Foliar sprays were initiated on September 30, 1993, three weeks after transplanting of (CV."Snow Crown") cauliflower. Treatments of the systemic insecticide Admire® 240FS, were applied at rates of 0.1, 0.13, and 0.25 lb (ai)/acre using a hand held single dose application gun on the soil at the base of each plant on September 8, 1993, immediately following transplanting and just prior to starting the sprinkler irrigation system. The lowest rate of Admire® 240FS of 0.1 lb (ai)/acre also received foliar treatments of Capture® 2EC + Thiodan® 3EC at rates of 0.08 and 1.0 lb (ai)/acre on September 30, October 7, 13, 20, and November 2, 1993. Lannate® LV was applied at 0.6 lb (ai)/acre on September 30, then in combination with Asana® 0.66EC at 0.05 lb (ai)/acre on October 7, 13, 20, 27, and November 2, 1993. Foliar spray treatments included in the tank mixture Sylgard® Silicone Surfactant at 8 fluid ounces per 100 gallons and Helena Buffer® PS at one pint per 100 gallons. The sprays with M-Pede® did not have Sylgard® 309 Silicone surfactant added to the tank mixture. All other foliar spray treatments were applied September 30, October 7, 13, 20, 27, and November 2, 1993. The remaining foliar treatments are listed: Capture® 2EC at 0.08 lb (ai)/acre, Thiodan® 3EC at 1.0 lb (ai)/acre, Capture® 2EC + Thiodan® 3EC at 0.08 and 1.0 lb (ai)/acre, respectively, M-Pede® as a 1% solution and as a 2% solution, M-Pede® as 1% and 2% treatments tank mixed each with Capture® 2EC at 0.08 lb (ai)/acre, M-Pede® as 1% and 2% treatments tank mixed with Thiodan® 3EC, Danitol® 2.4EC + Orthene® 75S at 0.2 and 1.0 lb (ai)/acre rates, respectively, Monitor® 2EC + Asana® 0.66EC, and an untreated control.

Admire® 240 FS treatments provided control of whitefly adults and nymphs for 40 days. Further control was only obtained in the 0.1 lb (ai)/acre rate of Admire® 240FS which received additional treatments with Capture® 2EC + Thiodan® 3EC, which was the most efficacious treatment in the experiment. All treatments with Capture® 2EC were highly efficacious as were the treatments of Danitol® 2.4EC + Orthene® 75S, Asana® 0.66EC + Lannate® LV, Monitor® 4 + Asana® 0.66EC, and Thiodan® 3EC + M-Pede® at the 2% rate. Treatments with M-Pede® alone and Thiodan® 3EC alone were much less efficacious.

Investigator's Name(s): Dennis R. Nelson, James S. Buckner, and Greg Walker.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January - December, 1994.

A Survey of the Chemical Composition of the Waxy Particles and the Cuticular Lipids of Whiteflies

Surface lipids, frequently the hydrocarbons, have been successfully used to differentiate closely related species and geographically separated populations of Diptera, Hymenoptera and Orthoptera. However, hydrocarbons are minor components of the surface lipids of whiteflies (Homoptera) and have not been useful as taxonomic indicators. Adult whiteflies are notable in that they are covered with copious amounts of waxy particles which are also scattered over their surrounding surfaces. We have shown that the lipids found on the exterior of adult whiteflies can be differentiated into two categories: the waxy particles and the lipids of the cuticular surface. The waxy particles are composed of a mixture of long-chain aldehydes and long-chain alcohols while the lipids of the cuticular surface are composed of wax esters with small amounts of hydrocarbons, and in the case of *Aleyrodes singularis* (kindly provided by Dr. Dan Gerling, University of Tel Aviv), small amounts of acetate esters. *A. singularis* adults also groom there nymphs and pupae by keeping them covered with waxy particles.

The carbon numbers of the major aldehydes and alcohols of the waxy particles from the oak whitefly *Aleuroplatus coronta* were C30, those from *Aleyrodes singularis* and from the greenhouse whitefly *Trialeurodes vaporariorum* were C32, those from the sweetpotato whitefly (strain A) *Bemisia tabaci* and the silverleaf whitefly (strain B) *Bemisia argentifolii* were C34, and those from the woolly whitefly *Aleurothrixus floccosus* and the bayberry whitefly *Parabemisia* myricae also were C34.

The carbon numbers of the major wax esters were C42 in *A. coronta* and *T. vaporariorum*, C42 and C44 in *A. floccosus* and *P. myricae*, C44 in *A. singularis*, and C46 in both *B. tabaci* and *B. argentifolii*.

The carbon numbers of the major acid/alcohol moieties of the wax esters were 20/22 in *A. coronta*, *A. floccosus* and *T. vaporariorum*, 20/24 in *P. myricae*, and 20/26 in both *B. tabaci* and *B. argentifolii*. *A. singularis* was unique with an acid/alcohol of 22/22 (and was also unique in the comparable amounts of acids 16, 18, 20, and 24 were present).

With the exception of *B. tabaci* and *B. argentifolii*, which could not be differentiated based on the components of their exterior lipids, all the other species studied in this limited survey could be differentiated based on differences in the composition of both the waxy particles (aldehydes plus alcohols) and their major cuticular surface lipids (wax esters), the differences in chemistry may be sufficient to allow recognition and differentiation by whiteflies and by parasites and predators.

Investigator's Name(s): Phil Odom, John Lublinkhof, and Fred Strachan.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1992, 1993, 1994.

Control of Whitefly with the Combination of OVASYN® + PHASER®

Data from field tests conducted the past 3 years in Arizona have shown that the combination of OVASYN + PHASER has provided good whitefly control while preserving early season beneficial insects, avoiding late season secondary pests, and providing an alternative chemistry.

The combination of OVASYN + PHASER is recommended by the University of Arizona and the Sticky Cotton Action Team as an early season management combination to preserve early season beneficials.

OVASYN @ 0.25 lb/ai/a + PHASER @ 0.75 lb ai/a has provided control of whitefly equal to pyrethroid combinations without secondary pest buildup that can be associated with multiple applications of the pyrethoid combinations.

The combination of OVASYN + PHASER can serve as a viable tool in resistance management and Integrated Pest Management Programs.

OVASYN, containing the active ingredient amitraz, has been documented to enhance the activity of other insecticides.

Investigator's Name(s): Juan Jose Pacheco-Covarrubias.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994 field season.

Response of Ninfal Instars of *Bemisia* spp. to Imidacloprid

Traditional methodologies for insecticide evaluation consider natural field infestations of the insect pest. In this way it is not possible to standardize the biological factors involved in the evaluation, therefore the probability that results of one test will repeat in another test is very low. This is due to the fact that the proportions of the immature instars that conform the population are different for each field. The objective of this research was to determine the response of each of the immature stages of the whitefly to a dosage of an insecticide. The study was conducted at the Yaqui Valley Experimental Station. The insecticide selected was imidacloprid applied at 105 g.a.i./ha. The methodology is described in the proceedings of the XXIX Congreso Nacional de Entomologia and 1994 Annual Meeting of the Southwestern Branch E.S.A. pp. 227-228.

Whitefly adults were collected in the field in order to make artificial infestations with 200 to 300 individuals. They were confined in organdy cages placed on leaves at the top of cotton plants. They were allowed for an oviposition period of 24 hours. In order to avoid unwanted oviposition, the organdy cages were placed five days before the artificial infestation. The adult infestation was carried out in eight randomly selected groups of plants. Mortality readings were realized at 5, 24, 48, and 96 hours after the insecticide was sprayed. One replication was used for the first three readings and four replications were used for the final reading.

For efficacy tests, analysis of variance was carried out with the four replication readings and mean separation was carried out by the Least Significant Difference method at the 0.01 level of probability. The insecticide efficiency was determined with mortality data obtained from the first three readings and the average of the last reading. This information was accumulated in order to obtain the regression lines and subsequently carry out the comparison of slopes among the different nymphal instars. The Abbott formula was used to correct mean mortality (Abbott, 1925). At the time when the insecticide was sprayed, the leaves that contained the N1 nymphs were located in node three. N2, N3 and N4 nymphs, were located on leaves in nodes four, five, and six, respectively.

Percent mortality corresponding to N1, N2, N3, and N4 were 47.75, 52.36, 38.46, and 10.23, respectively. The data show a differential mortality among treatments. The early instars being more susceptible than the late ones. For the efficacy test the slope values varied among the different nymphal instars. The slope values were 0.57, 1.14, 0.98, and 0.16 to N1, N2, N3, and N4, respectively. A clear difference is appreciated, in which the oldest nymphs were more tolerant to imidacloprid than the young ones. The N3 and N4 nymphs were 24 and 82 % more tolerant than N1-N2. The final analysis indicates that a clear difference exists among the several nymphal whitefly instars in relation to its susceptibility to imidacloprid, for this reason a method for evaluation of effectivity of insecticides should be established in order to determine nymphal stage effects and be able to compare results from different areas.

Investigator's Name(s): John C. Palumbo and Charles A. Sanchez

Affiliations & Locations: University of Arizona, Yuma Valley Agricultural Center, Yuma, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 – 1994.

Imidacloprid Does Not Enhance Growth and Yield of Cantaloupe in the Absence of Whitefly

Imidacloprid is a new insecticide currently being used to control sweetpotato whitefly (*Bemisia tabaci* Genn). Large growth and yield responses of cantaloupes (*Cucumis melo* L.) to imidacloprid have caused some to speculate that this compound may give growth and yield enhancement above that expected from insect control alone. Greenhouse and field studies were conducted to evaluate the growth and yield response of melons to imidacloprid in the presence and absence of whitefly feeding. Greenhouse cage studies showed plants exposed to sweetpotato whiteflies developed very high immature densities when not treated with imidacloprid. Significant increases in plant growth to imidacloprid were inversely proportional to whitefly densities. Positive growth responses to imidacloprid were not observed when insects were excluded from cages having cantaloupe plants. Results from a field study show similar whitefly control and similar yield response to imidacloprid and bifenthrin–endosulfan applications. Hence, we conclude that growth and yield response to imidacloprid is associated with control of whiteflies and the subsequent prevention of damage, rather than a physiological promotion of plant growth processes.

Investigator's Name(s): John C. Palumbo.

Affiliations & Locations: University of Arizona, Yuma Valley Agricultural Center, Yuma, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 – 1994.

Yield and Quality Response in Iceberg Lettuce to Whiteflies and Imidacloprid

Imidacloprid, a new insecticide, has recently been developed for control of sucking insect pests. Studies were conducted during the fall of 1993 and 1994 to investigate the effect of imidacloprid on silverleaf whiteflies, *Bemisia argentifolii* Bellows and Perring (also known as b–strain sweetpotato whitefly, *Bemisia tabaci* Genn.), in experimental plots and commercial fields of iceberg lettuce in Yuma, Arizona. Under experimental conditions at the Yuma Ag Center, small plot trials of treated and untreated lettuce were evaluated for efficacy and yield response. In commercial trials, field performance evaluations were conducted at seven sites in 1993 and six sites in 1994.

Populations of whiteflies in the respective experimental sites were moderate to high, with migratory populations active from plant emergence through the cupping stage. In general, untreated plots contained significantly greater numbers of whitefly eggs and nymphs than did imidacloprid plots throughout the season in both experimental and commercial tests. Colonization was significantly reduced ($P<0.05$) in imidacloprid plots as indicated by low incidence of eclosed pupal cases. Significant differences in plant vigor and growth were observed at various times in the season. At the thinning and cupping stages of growth, Relative Growth Rates of plants treated with imidacloprid were greater than untreated plants. At harvest, a significant yield response was observed in plots treated with imidacloprid. Quality, size and color were considered good in the imidacloprid plots. However, plants in the untreated plots were chlorotic, and head weight and size were significantly reduced. Overall, the control of silverleaf whitefly provided by imidacloprid and the associated yield and quality response of lettuce was considered excellent throughout the Yuma growing region.

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Affiliations & Locations: [1]University of California, Riverside, CA, and [2]USDA, ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology

Dates Covered by the Report: 1994

Insecticide Rotations as a Resistance Management Strategy for Whiteflies

Field trials were conducted at two sites in the Imperial Valley, CA to evaluate insecticide rotations as a resistance management strategy for whiteflies. Insecticide treatment regimens included continuous treatment plots with single insecticides using bifenthrin, endosulfan, chlorpyrifos and amitraz, rotation plots with the same four insecticides, and untreated control plots. All treatments were applied weekly, and bioassays of whiteflies collected from the respective treatment plots also were conducted weekly. Ten consecutive weeks of bioassay results failed to yield a discernible pattern for either the insecticide treatment regimens (continuous, rotation, untreated) or for any of the insecticides. However, significant differences among the various treatment plots were observed in the densities of preimaginal whiteflies infesting the plots and in the yield of cotton from the respective plots.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

Hydroponic Bioassay Technique to Monitor Responses of Whiteflies to Imidacloprid

A hydroponic bioassay technique was developed to monitor responses of whiteflies to imidacloprid. Differences in LC50 values were detected among three strains of silverleaf whiteflies using this technique. Preliminary data showed that the field collected strain (FS) from Imperial Valley exhibited low LC50 values (0.16-0.20 mg/ml) compared to the imidacloprid selected strain (IR) (1.32-2.59 mg/ml). The LC50 value of the reference strain (GH) was the lowest (0.03-0.05 mg/ml) using this technique. Detection of variation in responses among the strains suggest that this method is sufficiently sensitive to detect differences in susceptibilities of whitefly populations. The advantage of using this technique for monitoring resistance to imidacloprid in whiteflies is discussed.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: August 1994 - December 1994.

The test compared two rates (16 oz, 32 oz 2F per acre) of imidacloprid applied to cantaloupe, var Cruiser, either in a drip line placed 4 inches below the soil surface with approximately 15 psi in the line and 30 minutes irrigation time or as an in-furrow spray with ca. 30 gal. per acre. All treatments were made at planting (direct seeded) and all other cultural practices were the same in each plot. Significant differences were measured in seasonal averages of whiteflies and yield as follows:

	adults	s.nym	l.nym	wt.fru.	no.fru.	$value
1. Imidacloprid 16 oz drip	2.8 a	0.3 a	6.6 a	443 a	110 a	46.2 a
2. Imidacloprid 32 oz drip	2.1 a	0.3 a	3.7 a	386 a	104 ab	43.8 a
3. Imidacloprid 16 oz furrow	3.1 a	0.8 a	9.6 a	384 a	101 ab	42.3 a
4. Imidacloprid 32 oz furrow	3.6 a	0.3 a	4.9 a	410 a	100 ab	43.8 a
5. Untreated check	13.2 b	11 b	109 b	227 b	89 b	22.9 b.

There was not separation in measured variables between rates of imidacloprid in this test, probably because of the heavy influx of migrating whitefly adults at the beginning of the fall crop cycle. Heavy whitefly migrations in July and August have consistently occurred for the last four years in the Lower Rio Grande Valley of Texas. In this case, protection early in the crop cycle was the most critical. Only the 16 oz in-furrow treatment began to see some increase in nymphs at the end of the season, but this was not significant. The benefit from the imidacloprid treatment was self-evident based on the estimated dollar value (per 335 sq ft) and similar to previous trials.

Investigator's Name(s): David G. Riley and Weijia Tan.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January 1994 - December 1994.

Bifenthrin Resistance Studies

In 1993 studies were initiated to investigate resistance to insecticides in the b-strain of sweetpotato whitefly in Texas. Resistance was selected for using endosulfan, bifenthrin, acephate, and other compounds. Bifenthrin was selected for further studies on the inheritance of resistance and evaluations of fitness.

Bifenthrin resistance in b-strain of sweetpotato whitefly was inherited as a major single, incomplete dominance, sex-linked factor. In each of two parental strains, backcrosses to their respective hybrids demonstrated significant segregation. The resulting ratio were 0.6:1(SS/SR) and 1:0.9(RR/RS) rather than 1:1, and this was consistent with a plateau in backcross line at ca. 35-45% mortality. The estimate of dominance for the reciprocal crosses was different between R female x S male and S female x R male (0.91 and 0.51, respectively), suggesting that the additive inheritance of multiple genes or parental extranuclear effects might be involved. High, stable bifenthrin resistance (ca. 608-fold) was observed after selecting for a year.

Comparisons of bionomics data (i.e., fecundity, egg hatch, developmental time, and emergence) for the resistant (R) population, susceptible (S) population and crosses showed none or small differences in development time (RR=16, SS=16, RS=17, SR=18, RSR=17, RRS=17, SSR=18, SRS=19 days, female and male, respectively), differences in net reproductive rates (RR=23, SS=25, RS=11, SR=6, RSR=29, RRS=44, SSR=18, SRS=29), and similar adult survival among resistant and susceptible populations with greater differences between their reciprocal crosses. Oviposition patterns for the resistant population tended toward increased egg lay at the beginning of the 2-3 week oviposition period. These data suggest that stable bifenthrin resistance can develop and threaten resistance management in b-strain of sweetpotato whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: Research conducted in January and February 1994.

Susceptibility Tests for Some Common Insecticides Used for *Bemisia tabaci* (Gennadius) Collected from Cabbage in La Paz, B.C.S., Mexico

In Mexico as in other countries, the sweetpotato whitefly (SPWF) *Bemisia tabaci* (Gennadius) has become a high risk insect pest. This pest causes serious damage to several common crops, resulting in important economic losses to the agricultural sector. Baja California Sur, is the most arid Mexican state where agriculture is costly and trouble activity, mainly because of the water scarcity and the long distance from the mainland. Control of the SPWF in this region is usually done by intensive insecticide applications, either alone or in mixtures that include various insecticides. The objective of this work is to obtain data to detect any change in susceptibility of the SPWF population as an adaptive response of the selection pressure of excessive applications.

Glass vial bioassays were carried out on SPWF adults collected from cabbage plots located in La Paz agricultural valley. The adults were collected by means of a portable aspirator, a group of 20 whiteflies were introduced in a 20 ml scintillation vial coated in the inner surface with a known concentration of the insecticide tested. The vial was capped with a plastic cap that had two perforations covered with organdy for air penetration. Mortality readings were obtained three hours after exposing the insects to the residual activity of at least five insecticide concentrations. Five replications and a check were run in different consecutive days for each bioassay. The insecticides tested were cypermethrin, endosulfan, methamidophos and methyl parathion. The data obtained in three dates made during January and February 1994, showed LC_{50} values as follows: Cypermethrin 9.8, 5.5 and 7.7 μg/vial., endosulfan 823, 507 and 100 μg/vial., methamidophos 919, 673 and 602 μg/vial., methyl parathion 458, 350 and 334 μg/vial. These results indicate that cypermethrin was the most toxic to SPWF adults and methamidophos the least toxic. In general there was a decrease in the LC_{50} values from the first bioassay to the last, being this more marked with endosulfan. These data will be considered as base for further evaluations.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: August - November 1994.

Nicotiana Against *Bemisia argentifolii* in Three Vegetable Crops

Nicotiana glutinosa was evaluated in field crops of tomato, collard, and cantaloupe against *Bemisia argentifolii*. Field plots of each crop were set up consisting of a treatment of Lorsban 50 wp @ 2 lb/acre and a treatment of *N. glutinosa* (0.15%) @ 0.207 lb/acre. Similarly, a plot of each crop was set up in a screened field area (18.3 x 526.7 m) and treated with the above rates of Lorsban and *N. glutinosa*. Treatments were done by hand using a backpack sprayer. The nozzle was curved to enhance good under foliage coverage. Applications were made weekly. The open field test was run for 8 weeks after emergence and transplant; there were two trials of the screened plots test, both lasting four weeks. Data were collected on number of live adults whiteflies 2 days post treatment, and number of eggs and nymphs per selected leaf at 6 day post treatment, and on leaf area. Samples were stored in a freezer and are still being processed. Moreover, additional unprocessed samples were taken from a 6-week test in a field of tomato; there was much rain and overall whitefly infestation remained low in the tomato field.

The abundance of adult whiteflies on leaves was less in the Lorsban treatments than with the *Nicotiana* treatment. This trend was consistent over time and across each crop and in the open field plots as well as in the screen field plots. By week 4 in the tomato and cantaloupe plots, there were more above-ground plant biomass and taller plants or longer vines, although the plant condition was rated similar, for the *N. glutinosa* treated plants as compared with those treated with Lorsban. Conversely, there was more plant biomass in the Lorsban treated collard. By 8 weeks, tomato plant height was similar between treatments, but biomass continued to be greater for the *N. glutinosa* treatment.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994.

The Rationality of Biorational Insecticides for Control of Silverleaf Whitefly (*Bemisia argentifolii*)

The term "biorational" insecticide was coined but not defined in 1974 by Djerassi et al. (Science 186:596). These authors contrasted biorational insecticides by their species-specificity (low toxicity to non-target organisms) to broad-spectrum chemical insecticides and gave examples of naturally derived and synthetic materials. We believe that the term biorational insecticide should be defined as **any type of insecticide active against pest populations but relatively innocuous to non-target organisms, and therefore non-disruptive to biological control**. Our goal is to find means of chemically suppressing SLWF populations in ways compatible with biological control. Our initial approach was to compare insecticidal and repellent properties of a soap, a mineral oil, a surfactant-like extract of *Nicotiana gossei*, and a neem extract, with a pyrethroid (bifenthrin) against SLWF and three of its natural enemies. All materials tested by leaf-dip bioassay were highly toxic to young whitefly nymphs, but mineral oil and a synthetic pyrethroid (bifenthrin) were more toxic to all whitefly stages and more repellent to adults than the insecticidal soap or *N. gossei* extract. Residues of insecticidal soap and *N. gossei* extract were toxic to adult whiteflies only when wet. Toxicity of mineral oil, and to a lesser extent insecticidal soap, was greatly reduced when applied with a Potter tower, whereas bifenthrin was equally toxic whether sprayed or dipped. Thus, coverage was most critical to the functioning of oil which depends on topical activity, compared to bifenthrin which has systemic toxicity in the organism. Bifenthrin was highly toxic to adult *Chrysoperla rufilabris* but oil was more toxic to eggs. Neither soap, oil or neem extract was toxic to lacewing larvae. Bifenthrin was toxic to all stages of the coccinellid *Delphastus pusillus*, whereas *N. gossei* extract was not toxic to any life stages. Oil was moderately toxic to *D. pusillus* eggs and soap was quite toxic to larvae. Residues applied by dipping leaves in both bifenthrin and oil were highly toxic to adults of the parasitoid *Encarsia pergandiella*. However, the toxicity of oil residues was greatly reduced when sprayed rather than dipped. In conclusion, the surfactants, oils, and plant extracts tested were generally less toxic to natural enemies of SLWF than to the pest itself. However, all materials tested showed some toxicity to certain life stages of the three beneficial insects exposed so that "biorational" applied to these materials is a relative term. Field testing effects on SLWF and its natural enemies is our next step.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January 1993 - December 1994.

Development of a Resistance-Management Strategy for the Silverleaf (Sweetpotato) Whitefly

Baseline data were obtained in 1992 and 1993 on tolerance of the SPWF adult populations on different host crops (primarily spring melons, cotton and cole crops), to selected insecticides and insecticide mixtures in different geographical areas in Arizona, using treated glass vials. From these studies emerged the fact that host plants and crop phenology played a role in the tolerance of SPWF populations to some of the insecticide(s) tested, e.g., endosulfan, bifenthrin, fenpropathrin, acephate+fenpropathrin (5:1) and endosulfan+bifenthrin (10:1 ratio).

On comparing tolerances of SPWFs to fenpropathrin, bifenthrin and endosulfan from 1993 and 1994: i.) Tolerance to both bifenthrin and fenpropathrin increased during 1994 in the Phoenix area. In Yuma, there was an increase in tolerance in May and in June relative to 1993, but the populations were more susceptible later in summer. ii.) On the contrary, the tolerance to endosulfan decreased in 1994 relative to the tolerance exhibited in 1993 in both Phoenix and in Yuma. Only the populations found on cole crops in Yuma in October and November were more tolerant to endosulfan in 1994 relative to 1993. iii.) It is interesting to note that in 1993 (also seen in 1992) early season cotton populations (in June and July in Phoenix, and in May and June in Yuma) were much more susceptible to both bifenthrin and fenpropathrin, when compared to populations obtained from melons during this period. This disparity was no longer visible in early season cotton populations of 1994.

Fenpropathrin vs. Fenpropathrin+Acephate: There is potentiation of the toxicity of fenpropathrin, by adding acephate (1:5 ratio). However, populations in late summer were showing an increase in tolerance to the mixture in both the Phoenix and Yuma arteas, probably due to the continued use of the fenpropathrin+acephate mixture during the cotton season.

Bifenthrin vs. Bifenthrin+Endosulfan: On comparing the relative tolerances obtained using bifenthrin vs bifenthrin+endosulfan, there is a slight increase in toxicity in the September and October cotton populations, and in the populations on cole crops in Yuma. But, this is not perceived in the October populations on Cole crops in Phoenix (Note: complete set of data on bifenthrin+endosulfan is only available beginning in September, since range-finding studies had to be undertaken initially).

Determination of rate of resistance development when SPWF populations are subjected to selection pressure under laboratory conditions: A large, genetically diverse pool of SPWFs was collected from different crops, to establish a mixed colony in the laboratory. In selecting for resistance, adult whiteflies are being selected, by exposing them in treated glass vials at doses sufficient to give 60-80% mortality. The survivors are transferred onto clean plants held in large Perspex cages.

We presently have selected 5 generations of whiteflies. Three strains have been established in the laboratory: i.) Strain selected with fenpropathrin. ii.) Strain selected with fenpropathrin+acephate (1:5). iii.) The unselected founder strain.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January 1, 1994 - August 31, 1994.

Insecticide Tests

Bemisia tabaci strain A and *Bemisia argentifolii* strain B respond equally to bifenthrin and endosulfan when tested by glass vial bioassay technique. LC_{50} values, after 3 hours, as μg/vial were often statistically equal.

Selection of a greenhouse strain B with acephate, imidacloprid, amitraz methamidophos, fenpropathrin, and phenoxycarb for resistance was conducted during eight months in the greenhouse. Five sprays were made at various intervals and no increase in LC_{50} values for imidacloprid and fenpropathrin were determined. The increased LC_{50}s of adults following sprays of methamidophos indicated selection for resistance. LC_{50}s of adults for acephate, amitraz and phenoxycarb were variable.

Pyroproxyfen, fenpropathrin + acephate endosulfan and bifenthrin were effective following 12 sprays against B strain in field plots. Yields of lint were not increased following sprays compared to untreated check, but "sticky" cotton incidence was reduced to nonsignificant levels in treated plots compared to untreated plots. Azinphosmethyl was not effective against this pest species.

TABLE C. Summary of Research Progress for Section C – Chemical Control, Biorationals and Pesticide Application Technology in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
C.1 Identify for registration, new chemicals and formulations that effectively control SPW.	Yr. 3: Evaluate new chemicals in relation to stage of insect killed, economic threshold and effect on beneficials.	X		Significant progress was made in field evaluation of promising insecticides with activity against SLW. An experimental insect growth regulator, pryiproxyfen, showed excellent control of SLW as a foliar spray on cotton and melons. Research efforts among USDA, University and Industry scientists led to the registration or continuation of section 18's for use of Admire, Capture and Danitol in several states.
C.2 Identify for registration, biorational materials with new modes of action.	Yr. 3: Expand studies with best materials with highest potential. Evaluate efficacy, timing, alternatives with other chemicals.	X		Progress was made in 1994 to further examine plant derived and mineral oils, soaps and plant extracts with insecticidal and repellent activity against SLW. All materials tested were toxic to SLW nymphs via contact activity and generally less toxic to natural enemies than to SLW. Formulations of entomophagous fungi were tested against SLW under field conditions.
C.3 Develop application schedules and methods in relation to economic thresholds.	Yr. 3: Identify specific optimum controls in relation to SPW economic threshold.	X		Progress was significant in testing action thresholds based on SLW densities in cotton and cantaloupes. Relationships between SLW and sticky cotton were investigated in California, Arizona and Texas. Similarly, significant relationships of SLW adults and immatures with cantaloupe yield and quality were reported from Arizona and Texas.
C.4 Insecticide resistance studies.	Yr. 3: Determine insecticide dose relationships, discriminating doses, and hormoligosis.	X		Progress has been made in collecting baseline data of insecticide susceptibility to several active ingredients using the coated sticky card, glass vial and leaf dip techniques. Data has been collected from field populations in California, Arizona, Texas and Florida; and Sonoran and Baja California, Mexico. At present, resistance has not been reported in field populations.
C.5 Genetics of insecticide resistance in SPW.	Yr. 3: Use RAPD and restriction mapping techniques to ID markers associated with resistance genes.	X		Research progress was reported for genetic analysis of insecticide resistance in SLW. Studies with bifenthrin have been conducted to investigate inheritance of resistance and evaluations of fitness. PCR-based molecular diagnostics were used to investigate cyclodiene resistance in *B. tabaci* biotypes.
C.6 Develop methods for application or delivery of materials to improve control.	Yr. 3: Determine efficacy, with best coverage application equipment.	X		Further progress was made to compare methods of ground and air application for deposition of sprays to ventral surfaces of leaves. Studies of aerial application showed that spray deposition on plant leaves can be affected by airspeed and nozzle types. Significant progress has been made in developing improved aerial application technology. Electrostatic charging of sprays delivered from aircraft is being evaluated and has shown promise for improving deposition.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Yr. 3: Compare rates, combinations, application technology on natural enemy populations.		X	Although progress was made in studying the impact of chemicals and biorationals on natural enemies, no significant progress has been made on evaluating application methodologies on the SLW and natural enemy complexes.

Research Summary
Section C: Chemical Control, Biorationals, and Pesticide Application Technology
Compiled by: John C. Palumbo and Philip A. Stansly

C.1 Identify for registration, new chemicals and formulations that effectively control silverleaf whitefly (SLW).

It was suggested that the research approaches and goals statements for sections C1. and C2. be combined so that we identify for registration new chemicals with novel and specific modes of action that effectively control SLW.

For a second year, cooperative research efforts among USDA–ARS, University and Industry scientists led to the registration or the securing of section 18's allowing the use of new insecticides for the control of SLW. Among the most prominent materials obtained for grower use were Admire (imidacloprid), Capture (bifenthrin), and Danitol (fenpropathrin).

Efficacy of many materials against SLW continued throughout SLW infected areas. The following materials were tested for SLW control: Admire (imidacloprid), Thiodan (endosulfan), Ovasyn/Mitac (amitraz), Fenoxycarb, Applaud, (buprofezin), Capture (bifenthrin), Aliette (fosethyl), Lorsban (chlorpyrifos) Asana (esfenvalurate), Lannate (methomyl), Temik (aldicarb), Danitol (fenpropathrin), Pyriproxyfen, Monitor (methamidophos), Orthene (acephate), Vydate (oxamyl), Agri–Mek (abamectin), CGA 215944 (pymetrizene) and Karate (lambda–cyhalothrin). The above materials were tested individually, in combination or tank–mixed with biorationals. Admire, pyriproxyfen, combinations of Danitol + Orthene, Capture + Thiodan showed the greatest activity against SLW.

C.2 Identify for registration, biorational materials with new models of action.

A biorational insecticide was defined as: any type of insecticide active against pest populations but relatively innocuous to non–target organisms, and therefore non–disruptive to biological control. The goal of scientists working with these materials was to find a means of chemically suppressing SLW in ways compatible with biological control.

Studies were conducted to investigate the activity of biorationals against SLW and selected natural enemies. The repellant and insecticides properties of soap, mineral oil, *Nicotiana gossei*, neem and bifenthrin were compared. All materials were toxic to young nymphs in leaf–dip bioassays, and oil and bifenthrin were more repellent to adults than the other materials tested. In general, coverage appeared to be most important to the functioning of oil. The soap, oil and plant extracts tested were generally less toxic to natural enemies than to the SLW.

Two entomophogus fungi, *Paecilomyces fumosoroseus* strain PFR612, and *Beauveria bassiana* Strain 401 were evaluated on melons and cotton in 1994. These materials provided moderate control of SLW populations in the Imperial Valley. Both fungi had no adverse impact on the action of the natural enemy populations present.

C.3 Develop application schedules and methods in relation to economic thresholds.

Progress was made in 1994 to define and validate action thresholds on cotton and cantaloupes. Results thus far have been positive and basically relate insect density (adults and nymphs) to timing of applications. In cotton, action thresholds of 3, 5, and 10 adults per leaf have been evaluated. In cantaloupes, action thresholds of 1, 3, 6 and 10 adults per leaf, and 0.5, 1 and 2 nymphs per 7.6 cm^2 have been tested.

Relationships between SLW populations and sticky cotton have been investigated in California, Arizona and Texas. Significant correlations between these two variables were reported in California. Similarly, significant relationships of SLW adults and immatures with cantaloupe yield and quality were reported from Arizona and Texas. Preliminary work was noted for cole crops and alfalfa. Preliminary work has also been initiated to develop economic injury levels for SLW on cotton.

C.4 Insecticide resistance studies

It was suggested that the research approaches and goals statements for sections C4. and C5. be combined in 1995 to group insecticide resistance work into three areas: monitoring, mechanisms and management.

In terms of resistance monitoring, several bioassays are currently in use for providing baseline data of several active ingredients. The bioassays which are currently being utilized and compared are the coated sticky card, glass vial, and leaf dip techniques. Baseline susceptibility data has been collected from field populations in California, Arizona, Texas and Florida with the following chemicals: bifenthrin, endosulfan, fenpropathrin, acephate, imidacloprid, amitraz, and methomyl. In addition, baseline data from field populations with cypermethrin, methyl parathion, endosulfan and methimidaphos has

been collected from Sonora and Baja California, Mexico. At present, resistance has not been reported in field populations.

Work was continued to investigate SLW resistance development when used in rotations and mixtures of insecticides were used when compared with continuous selection of individual active ingredients.

C.5 Genetics of insecticide resistance in SLW.

Research progress was reported for genetic analysis of insecticide resistance in SLW. Studies with bifenthrin have been conducted to investigate inheritance of resistance and evaluations of fitness. Backcrosses of two parental strains were used to study select stable bifenthrin resistance for studies on the genetic inheritance of resistance and bionomics of resistant and susceptible crosses under controlled conditions. In addition, two PCR–based molecular diagnostics were used to investigate cyclodiene resistance in *B. tabaci* biotypes.

C.6 Develop methods for application or delivery of materials to improve control.

It was suggested that the research approaches for sections C6. & C7. be combined in 1995 to evaluate application methodologies.

Work to compare methods of ground and air application for estimation of underleaf coverage was continued. Ground application of insecticides on tomatoes, cotton, lettuce and cauliflower in Arizona and California indicate that electrostatic, high air–volume sprayers and controlled droplet applicators gave no advantage over conventional hydraulic sprayers for spray deposit on the undersides of leaves. Studies in Georgia on squash showed that air boom sprayers provided better efficacy against SLW that electrostatic and hydraulic sprayers. The response of SLW to spray droplet characteristic on cotton showed that spray droplet size and density did not influence SLW mortality. Other work in cotton has investigated increasing volume and pressure of conventional hydraulic equipment.

Significant progress has been made in evaluating and developing improved aerial application technology. Studies of aerial application in Texas showed that spray deposition on plant leaves can be affected by airspeed and nozzle types. Electrostatic charging of sprays delivered from aircraft is being developed and has shown promise for improving deposition. Research has been initiated to develop spray systems that increase spray deposition with smaller drops and improved retention to plant foliage.

C.7 Evaluate application methodologies for impact on natural enemies and SLW interactions.

Although progress was made in studying the impact of chemicals and biorationals on natural enemies (see section C2. and D.7), no significant progress has been made on evaluating application methodologies on the SLW and natural enemy complexes.

Reports of Research Progress
Section D. Biological Control
Co-Chairs: Oscar Minkenberg and Kevin Heinz

Investigator's Name(s): Matthew Ciomperlik, John Goolsby, Ron Hennessy, Dale Meyerdirk, Paul Parker, Don Vacek, Lloyd Wendel.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: November 1993 - November 1994.

APHIS Biological Control Program Against *Bemisia tabaci*

SPWF populations in the Lower Rio Grande Valley (LRGV) of Texas were highest on cucurbits and cotton in late spring and summer; populations on winter vegetables were moderate. Six weeds harbored low-to-moderate densities of SPWF. Increases in parasite populations began in Feb., populations decreases were sharp in Dec. and Jan. Predators collected from LRGV cotton were shipped to J. Hagler (ARES, Tucson, AZ) who used a monoclonal antibody test to test their relative importance as SPWF egg predators. The order of importance from greatest to least was *Chrysoperla* adults > *Geocoris* adults > *Chrysoperla* nymphs > *Geocoris* nymphs > *Nabis* adults. In an effort to detect geminiviruses which potentially might be transmitted to crops by SPWF in the LRGV, the Mission Biological Control Laboratory (MBCL) extracted viral DNA from various road-side and field side plants displaying symptoms. J. Brown (Univ. AZ, Tucson) confirmed the presence of geminiviruses in nine plant species representing six families.

In 1994, additional species of natural enemies were imported from Argentina, Brazil, Cyprus, Italy, Israel, Malaysia, the Philippines, Taiwan, Thailand. Foreign collection was accomplished by A. Kirk and L. Lacey (ARES European Biological Control Laboratory, Montepellier, France), M. Rose (Texas A&M Univ., College Station), C. Moomaw (Texas A&M Univ., ARES funding), J. Legaspi, R. Carruthers, T. Popraski (ARES, Weslaco, TX). Thirty-five species or strains of *Eretmocerus* and *Encarsia* (Aphelinidae) and an undescribed species of *Serangium* (Coccinellidae) were in culture at the end of the year.

MBCL produced about 6.5 million SPWF parasites in 1994, most of which were sent to cooperators for release. During the field season, parasites were produced routinely in 10-ft x 10-ft cage at an average rate of 40,000/cage/week. With modified methods, yields were 60% lower but nearly free of whitefly contaminants. Twelve exotic species/strains were released in the Lower Rio Grande Valley (LRGV) and Wintergarden areas of Texas, three of which were recovered in post-releases sampling. One, *Encarsia transvena*, spread rapidly out from release sites in the LRGV. MBCL supplied seven species of parasites to Kim Hoelmer (APHIS, Methods Development, Brawley, CA) and G. Simmons (APHIS-PPQ-WR, Brawley, CA); releases were made in urban areas of AZ and the Imperial Valley of CA. In the San Joaquin Valley of CA, MBCL in cooperation with C. Pickett, L. Bezark, and J. Ball (California Dept. of Food and Agriculture), and Bill Abel (PPQ- Bakersfield) have released seven species of parasites in urban areas, two of which have been recovered. One species, *Encarsia transvena* from Murcia, Spain has been recovered in large numbers from Bakersfield and Lamont, CA.

In controlled field experiments on cotton at MBCL, *Encarsia transvena* from Spain, *Eretmocerus* sp. from Spain, *Eretmocerus* sp. from India, and *Eretmocerus* sp. from College Station, TX were evaluated against native *Eretmocerus* sp. and *Encarsia pergandiella*. Parasitism was higher with *E. pergandiella* than with other species.

MBCL in cooperation with J. Sanderson and R. Ferrentino (Cornell Univ.) and J. Weaver (Univ. NH) and J. McAvoy (Univ. CT) tested the Nile Delta strain of *Encarsia formosa* against SPWF on tomato and poinsettia in greenhouses. In NH four releases totalling 90 parasites/plant reduced mixed (50-50) populations of SPWF and greenhouse whitefly adults on tomato by 85%. Five weekly releases of two adults/plant reduced a pure infestation of SPWF nymphs on poinsettia by 96%. Parasitization of SPWF seldom exceeded 35% indicating that host-feeding may be more important than parasitization.

Investigator's Name(s): Matthew A. Ciomperlik[1], James B. Hagler[2].

Affiliations & Locations: USDA, APHIS, PPQ, Biological Control Laboratory, Mission, TX[1]; USDA, ARS, Western Cotton Research Laboratory, Tucson, AZ[2].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Survey of Native Predators for SPWF Egg Predation in Cotton in the Lower Rio Grande Valley, Texas

Approximately, 1,000 individuals of five predator species were collected from cotton that showed heavy infestations of Sweetpotato whitefly (SPWF), (*Bemisia tabaci*, biotype B). Predators were collected by sweepnetting, and were stored in crushed ice for transport to the laboratory. Additional samples, to be used as negative controls, were collected and stored in cardboard containers for transport to the laboratory. Predator samples for assay were sorted according to species, adult or nymphal stage, and were stored frozen at - 80°C. Negative control samples were sorted to species, caged, and allowed to feed ad libitum for 72 hours on cabbage looper (*Trichoplusia ni*) larvae, water, and honey. Negative control individuals were stored as described above. Individual predators were assayed for SPWF egg predation using a monoclonal antibody test (Hagler et al. 1993).

Both adults and nymphs of five predator species were collected during this study, they were: *Chrysoperla rufilabris*, *Geocoris punctipes*, *Orius insidiosus*, *Nabis alternatus*, and *Nabis americoferus*. The most abundant species sampled included *C. rufilabris* and *G. punctipes*. Approximately 13% (n=300) of *C. rufilabris* nymphs and 100% (n=110) of the adults scored positive for SPWF egg predation. However, nymphs of *C. rufilabris* were used as negative controls for assays of field collected *C. rufilabris*, because field collected adult controls did not survive 72 h on the control diet. Fifty-five percent (n=22) of nymphs and 19% (n=280) of adult *G. punctipes* scored positive for SPWF egg predation. A few *N. alternatus* adults scored positive, 14% (n=7), while the none of the nymphs of that species scored positive (n=11). Both adults and nymphs of *N. americoferus*, and adults of *O. insidiosus* showed 0% scoring positive for SPWF egg predation.

These data suggest that larvae of *C. rufilabris* and both adults and nymphs of *G. punctipes* may contribute to SPWF population suppression by egg predation in the field. The large proportion of *C. rufilabris* adults that scored positive was most likely due to the use of larvae as negative controls. Future studies will attempt to used other negative control diets for adult *C. rufilabris*. Observations during the field collections showed that *C. rufilabris* larvae were often collected from strata within the plant canopy where SPWF nymphs greatly outnumbered eggs. In addition, many of the *C. rufilabris* larvae had their mandibles in the SPWF nymphs cuticle. The monoclonal antibody test (Hagler et al. 1993) can only test for the presence of SPWF egg protein in the gut of a predator. Field observations, combined with the relatively low percent scoring positive, suggest that *C. rufilabris* nymphs may feed more heavily on whitefly nymphs than on eggs.

Investigator's Name(s): Matthew A. Ciomperlik, Juan M. Rodriguez, Lloyd E. Wendel.

Affiliations & Locations: USDA, APHIS, PPQ, Mission Biological Control Laboratory, Mission, TX.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Assessments of Sweetpotato Whitefly (*Bemisia tabaci*, Biotype B) and Indigenous Parasite Populations in Agroecosystems of the Lower Rio Grande Valley, Texas

During 1994, USDA, APHIS, PPQ, Mission Biological Control Laboratory and APHIS, PPQ, Central Region personnel surveyed 28 field sites for Sweetpotato Whitefly (SPWF) and indigenous natural enemies. The field sites were located along four major highways that transect the four counties that comprise the Lower Rio Grande Valley (LRGV). Data collected in the field included: crop type and growth stage, adult whitefly per leaf via vacuum sampling, and weather conditions. Leaf samples of crops and weedy plant species that supported immature whitefly were collected from the field and returned to the laboratory. Counts of whitefly nymphs and parasitized nymphs were made in the laboratory. Parasitized nymphs were held for emergence and adult parasites were identified and separated according to species, sorted to gender, and counted. Several trends in SPWF and parasite populations are discernable from this data.

Low to moderate SPWF population densities were observed in winter vegetables like cabbage, broccoli, and Swiss chard. SPWF populations moved from winter vegetables to spring melons and cucurbits, reaching damaging population levels in both crops. SPWF populations migrated from these crops to cotton, where they continued to increase. The SPWF population reached peak numbers in the summer months of June and July. Defoliation of cotton in August forced a migration of SPWF to fall vegetables that include melons, cucurbits, and crucifers. Six weed species were also found to harbor low to moderate SPWF densities. Of these weeds, Sowthistle (*Sonchus oleraceae*) and redroot pigweed (*Amaranthus retroflexus*) supported the greatest SPWF populations. These two weeds are very prevalent in the LRGV, most often in row crops, crop turn-rows, and arable fields.

Seven parasite species of SPWF were collected and identified from the crop and weedy plant samples. The seven parasite species, in order of greatest abundance to least, were: *Eretmocerus* sp. nr. *californicus*, *Encarsia pergandiella*, *Encarsia meritoria*, *Encarsia* sp. nr. *strenua*, *Encarsia luteola*, *Encarsia nigricephala*, and *Encarsia formosa*. *Er*. sp. nr. *californicus* and *En. pergandiella* occurred in about 95% of all the samples, and both appear to have a cosmopolitan distribution throughout the LRGV. Population trends of the two most abundant parasite species were similar to that of SPWF. Parasite populations were low in winter months in crucifer crops, increased in spring melons and cucurbits, and reached peak numbers in summer months in cotton. Parasite populations declined slightly during the fall in cucurbits and melons.

It is becoming increasing evident that the native natural enemy assemblage in the LRGV is incapable of controlling SPWF populations below economic injury levels. Therefore, attempts at establishing exotic natural enemy species into the valley's agroecosystems are warranted. The information gathered thus far in the LRGV studies has helped us to: (1) establish baseline data on SPWF abundance, (2) determine the major crops affected by this pest, and 3). the extent of the native parasite complex. This information will be used to help us form an action plan for releasing exotic parasite and predator species in the LRGV in 1995.

Investigator's Name(s): Abd El-Ghany, M. El-Sayed, and Galal M. Moawad.

Affiliations & Locations: Plant Protection Research Institute, A.R.C. Dokki, Giza, Egypt.

Research and Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1992 - 1993.

Ecological and Biological Studies on *Encarsia Lutea* a Primary Parasite of *Bemisia tabaci* in Egypt

Field experiments were conducted throughout 1992 and 1993 seasons to study the role of natural enemies in suppressing *Bemisia tabaci* on some host plants which growing in two areas, i.e., new reclaimed land (El-Tahrir) and Delta land (Menoufia governorate). *Encarsia lutea* and *Eretmocerus mundus* were an effective role as natural enemies, followed by predators which associated with insects infestation. However, the fungus had a light role in larvae and pupae of *B. tabaci*. Percentages of parasitism were estimated for each area in different host plants showed the highest percentages of parasitism occurred on the hosts in new reclaimed land.

Laboratory studies were carried out to determine the optimum temperature and food requirements of *E. lutea* for maintaining the longest lifespan. Results showed that the temperature and type of food was significantly intereffect on the longevity of *E. lutea* adults. The longest periods of adults longevities were kept at 27°C and 60-75% R.H. and fed on bee honey, while the shortest period occurred when kept at 37 and 12°C.

Investigator's Name(s): L.D. Godfrey[1], P.B. Goodell[2], T.M. Perring[6], T.S. Bellows[6], C.G. Summers[3], W.J. Bentley[4], T. Prather[2], and R. Coviello[5].

Affiliations & Locations: Department of Entomology, University of California, Davis[1]; Statewide Integrated Pest Management Project, University of California, Kearney Agricultural Center[2]; Department of Entomology, University of California, Davis, Kearney Agricultural Center[3]; Cooperative Extension, University of California, Bakersfield, CA[4]; Cooperative Extension, University of California, Fresno, CA[5]; Department of Entomology, University of California, Riverside[6].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1 January 1994 - 31 December 1994.

Incidence of Parasitism of Silverleaf Whitefly in the San Joaquin Valley

Parasitism of silverleaf whitefly (SWF) nymphs was studied from specimens sampled on crop and weed hosts within twelve sample sites (36 sq. mi. each) in Kern, Kings, Tulare, Fresno, and Merced counties in the San Joaquin Valley (SJV) of California. Sampling in these areas began on 1 May 1993 and has continued to the present. Results from 1994 will be reported herein. SWF nymphs were collected in the field, from a 10-minute search made every 2 weeks, and held in the laboratory for parasitoid emergence.

In 1994, ~20,000 SWF nymphs were examined for parasitism. From the Kern county (southern SJV) sites, parasitized SWF nymphs were identified from crop plants including honeydew melons, cotton, alfalfa, sweet potato, and tomato and from weeds including smooth pigweed, black nightshade, and morningglory. The first collection of parasitized SWF nymphs was on 28 June; however, parasitism incidence generally increased later in the growing season (20 September). In summary, overall percentage parasitism was 1.5% (0.4% *Encarsia* spp., 1.0% *Eretmocerus* spp., and 0.1% unidentified [died before emergence]). The incidence of parasitism in 1994 increased slightly from 1993, when 0.2% parasitism was found.

In the Kings, Tulare, and Fresno county sites in 1994 (south-central to central SJV), overall percentage parasitism was 0.5%. This was comprised of 0.1% *Encarsia* spp., 0.2% *Eretmocerus* spp., and 0.2% unidentified. Parasitism was noted on cotton, tomato, velvetleaf, and black nightshade from 21 June to 3 October. In 1993 in these areas, parasitism was only ~0.1%, therefore a slight increase occurred in 1994. Some of the 1994 sample sites in this study were near (within 1 mile) of known sites of parasitoid release, but we believe our data generally represent the background level of SWF parasitism in the SJV.

Investigator's Name(s): Ned M. Gruenhagen, Thomas M. Perring, Tom S. Bellows, Jr., and Charles A. Farrar.

Affiliations & Locations: Department of Entomology, University of California, Riverside, CA 92521

Research & Implementation Area: Section D: Biological Control.

DATES COVERED BY THE REPORT: January 1994 - January 1995.

Alteration of the Silverleaf Whitefly's Host-Plant Environment to Influence Parasitism

Results from surveys of whitefly populations in the Imperial Valley of California showed that parasitism by *Eretmocerus* was relatively high on the native plant, camphor weed (*Heterotheca psammophila*). These observations led to an experimental examination of the feasibility of using this plant in companion plantings to increase the natural rate of parasitism of whiteflies on melons. Wild *H. psammophilla* plants were transplanted to field plots at the Desert Research and Extension Center in Holtville, CA, and at the Agricultural Operations on the UC Riverside campus (UCR). After establishment of the camphor weed plots, cantaloupe (cv. Topmark) was planted in the field. Within each plot, sampling points were arrayed at 1.5, 2.4, 3.0 and 4.5m from plantings of camphor weed or melon (control) at the center of each plot .

Plantings were allowed to be colonized naturally by whiteflies. The underside of melon leaves within ca. 0.3m of each sampling site were examined and those having late instar (3rd and 4th) whitefly nymphs were clipped from plants, bagged, placed into a cooler and transported to the laboratory where they were refrigerated. Sufficient material to later sample 100 red-eye nymphs in the laboratory was collected when available, although a minimum of three leaves was collected where whitefly densities were great. Densities of whiteflies on camphor weed averaged less than 1 nymph per leaf at UCR and all leaves could not be examined, so 30 minutes were allocated to locate leaves with nymphs. In the laboratory, the leaves were examined microscopically and the ratio of pupal *Eretmocerus* parasites to red-eye nymphs in a sample of up to 100 such individuals was enumerated.

At both locations, parasite density was lower than anticipated. The rate of parasitism of whitefly nymphs on camphor weed ranged from 14.0% to 16.4% and was similar between dates and among locations. No trends in levels of parasitism were apparent. Parasitism was not present on melon plants, hence levels of parasitism on camphor weed and melon were significantly different (all $P<0.05$) across all dates at both locations. These results validated survey results indicating that whiteflies on camphor weed suffer higher rates of parasitism than those on melons, although the levels of parasitism recorded on camphor weed were lower than many of those recorded from surveys of natural stands of camphor weed in the Imperial Valley in 1992 and 1993.

Camphor weed did not exert a general influence on parasitism at the level of an individual plot. Levels of parasitism were not significantly different for whiteflies in treatment and control plots for four of five sample dates. A significant difference in the level of parasitism was recorded on one sampling date at UCR, however, in all cases the average level of parasitism was less than 0.01%. Distance of whitefly nymphs on melon plants from camphor weed plantings also did not influence their level of parasitism. Although levels of parasitism were often relatively highest closest to the camphor weed plantings, the average level of parasitism always was less than 0.01% for whiteflies at 1.5, 2.4, 3.0 and 4.5m distant from them.

Investigator's Name(s): Ned M. Gruenhagen, Thomas M. Perring and Tom S. Bellows, Jr.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1994 - January 1995.

Searching Behavior of *Eretmocerus* sp. on Glabrous and Hirsute Melon Varieties

The searching behavior of *Eretmocerus* sp. on excised melon leaves infested with whitefly nymphs was studied in small arenas in the laboratory. We recorded the behavior of individual parasites on leaves from three melon types: a hirsute melon variety and glabrous isoline, and also on a hirsute commercial variety.

Activities associated with searching, assessing, or probing host whiteflies accounted for approximately 40% of the total time the parasites spent on leaves. The proportion of time allocated to walking, antennating or probing hosts did not differ significantly among melon types. Grooming and resting behavior accounted for 37-45% of the activity budget of the parasites while on leaves, but neither activity varied significantly among melon types. Host feeding events were infrequently recorded, although this activity accounted for 12-17% of the total time on leaves. Other activities accounted for less than 5% of the time spent on leaves and did not differ among melon types.

The number of whitefly nymphs probed on each of the three melon types was similar. However, for those nymphs that were probed in ovipositional attempts, eggs were deposited under a higher proportion of nymphs on the glabrous isoline. This suggests that parasites may have been more successful at parasitizing nymphs on this melon type.

Investigator's Name(s): Moshe Guershon and Dan Gerling.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1994 - November 1994.

Tritrophic Relationships Involving *Bemisia* and *Delphastus Pusillus*

When *Bemisia tabaci* is reared on tomentose leaves, a majority of its pupae develop a setose phenotype. In previous work, this phenotype was found to differ in some developmental and morphometric characteristics (adult size and development duration). In the present work we report some effects of these phenotypes on predator-prey interactions. The walking behavior and the time allocation (defined as the proportion of time devoted to each of four behavioral events: searching, handling, feeding and 'others') of the coccinellid *Delphastus pusillus*, were examined. The beetle's time allocation was tested while preying upon setose vs. smooth *Bemisia tabaci* pupae, on cotton leaves that differ in their pubescence.

Although a higher handling time was recorded for the setose pupae on all substrates, this did not affect the efficiency of preying (expressed as the number of prey consumed per search time). However, an increase in the efficiency of preying was found when the predator was exposed to smooth whitefly pupae on tomentose leaves.

The observations of walking behavior were performed on tomentose vs. glabrous leaves devoid of whiteflies or their cues (honeydew, etc.). Significant differences between the walking patterns on the different leaf kinds were found.

From these results, we suggest that being smooth on tomentose leaves is non-adaptive for the immature whitefly since it decreases the predator's search and handling times. Additional tests checking the preference towards the less adaptive morph by the predator are being performed presently.

Our results enforce the need for a tritrophic perspective when studying and analyzing ecological systems especially when intending to utilize the results for biological control.

Investigator's Name(s): James Hagler & Steve Naranjo.

Affiliations & Locations: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Characterizing and Estimating the Effect of the Native Predator Complex of Sweetpotato Whitefly

Work continued on characterizing and estimating the effect of the native predator complex of sweetpotato whitefly using a pest-specific monoclonal antibody. To date we have estimated the frequency of predation on whitefly for nine species of predators for three seasons. Our recent emphasis is on integrating this information with data on predator population density, predator functional response behavior, and predator digestive physiology. Analysis indicate that, although certain predator species may show high frequencies of predation on specific sampling dates, many of these species exist at relatively low population densities. Based on both frequency and population density *Orius tristicolor* and *Lygus hesperus*, a serious pest of cotton and other crops, are the dominant predators of the whitefly egg stage. Minor predation can be credited to *Collops vittatus, Geocoris punctipes, G. pallens, Hippodamia convergens*, and *Nabis alternatus*.

Investigator's Name(s): David H. Headrick, Thomas S. Bellows, Thomas M. Perring.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1 - December 31, 1994.

Behavior of *Eretmocerus* sp. nr. *Californicus* Females Attacking *Bemisia argentifolii* on Two Native California Weeds

Searching and ovipositional behaviors by *Eretmocerus* sp. nr. *californicus* (Aphelinidae: Hymenoptera) females on *Bemisia argentifolii* Bellows & Perring (Aleyrodidae: Homoptera) infesting velvetleaf, *Abutilon theophrasti* Medic. (Malavaceae) and telegraph weed, *Heterotheca grandiflora* Nutt. (Asteraceae) were quantified. Adult female behaviors were described and quantified for *Eret.* sp. nr. *californicus* to establish a behavioral time budget analysis. Females departed from leaves of *H. grandiflora* in 44.4% of the trials, and those remaining readily searched for whitefly hosts with walking speeds averaging 0.26 mm/sec. For *A. theophrasti*, females departed from the leaves in 83.3% of the trials, and of those that remained and searched for hosts, walking speeds averaged 0.29 mm/sec. The duration of host assessment by antennation was related to subsequent behaviors, rejecting a host was a shorter process than accepting it for further evaluation irrespective of plant species or nymphal stage. Evidence for a behavioral preference for oviposition under early instars was documented for *Eret.* sp. nr. *californicus* females on both plant species. Oviposition efficiency in 1 hr long laboratory trials for nymphs on *A. theophrasti* was 30% while efficiency on *H. grandiflora* was 23%. Of the total time spent on *A. theophrasti*, 61.9% of a female's time was spent in searching, host assessment, probing and oviposition, while on *H. grandiflora* these activities accounted for 53.3% of the total time. The remainder of the time was spent grooming, resting, and host feeding, except host feeding on *A. theophrasti* was not observed.

Investigator's Name(s): David H. Headrick, Thomas S. Bellows, Thomas M. Perring.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1 - December 31, 1994

Behaviors of Female *Eretmocerus* sp. nr. *Californicus* (Hymenoptera: Aphelinidae) Attacking *Bemisia argentifolii* (Homoptera: Aleyrodidae) on Sweet Potato, *Ipomoea Batatas* (Convolvulaceae)

The behaviors of *Eretmocerus* sp. nr. *californicus* females on *Bemisia argentifolii* Bellows & Perring infesting sweet potato, *Ipomoea batatas* (L.) Lam. were described and quantified. Walking speeds of up to 1.3 mm/sec were calculated for females searching for host whitefly nymphs on sweet potato leaves. Females encountered all host stages during searching with approximately the same relative frequency as their relative abundance (average of 17.03% of hosts available were encountered). Females also arrested and antennated all of the host stages with the same relative frequency as their encounter rate (62.8%). Females showed a clear and significant preference for probing second instars over all other stages. Of the hosts probed, females chose all stages for ovipostion with the same relative frequency. Successful exsertion of the ovipositor under a host nymph occurred after initial probes 12 times and after repeated probing attempts 15 times. Oviposition occurred under 13.5% of the hosts assessed by antennation; however, 20 of the 27 (74%) nymphs under which the ovipositor was exserted received an egg. Females spent 41% of the total time in searching, host assessment, probing and oviposition, while the remainder of the time (59%) was spent host feeding, grooming, and resting.

Investigator's Name(s): David H. Headrick, Thomas S. Bellows, Thomas M. Perring.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1 - December 31, 1994

Female Behaviors of *Eretmocerus* sp. nr. *Californicus* (Hymenoptera: Aphelinidae) Attacking *Bemisia argentifolii* (Homoptera: Aleyrodidae) on Cotton, *Gossypium Hirsutum* (Malavaceae) and Melon, *Cucumis Melo* (Cucurbitaceae)

Behaviors of *Eretmocerus* sp. nr. *californicus* females attacking *Bemisia argentifolii* Bellows & Perring infesting cotton, *Gossypium hirsutum* L. and melon, *Cucumis melo* L. were quantified. Adult female behaviors were described and quantified for *Eret.* sp. nr. *californicus* to establish a behavioral time budget analysis. Females readily searched for host whitefly nymphs on cotton leaves with walking speeds averaging 0.5 mm/sec. Females remained infrequently on melon leaves; of those that did remain and search for hosts, they averaged walking speeds of 0.33 mm/sec. The duration of host assessment by antennation was related to subsequent behaviors. Rejecting a host was a shorter process than accepting it for further evaluation irrespective of plant species or nymphal stage. Probing the margins of the host nymph by the female parasite with her ovipositor was repeated less frequently on an individual host on melon leaves than on cotton. Evidence for a behavioral preference for oviposition under early instars was documented for *Eret.* sp. nr. *californicus* females on both plant species. Oviposition efficiency for the females that remained and searched for nymphs on leaves in 1 hr long laboratory trials on cotton measured 18%, while efficiency on melon was 55%; this high percentage was due to a morphological variation in nymphs on melon leaves. Twenty-six percent of a female's time on cotton leaves was spent in searching, host assessment, probing, and oviposition, while on melon leaves these behaviors accounted for 44% of the total time. The remainder of the time was spent host feeding, grooming, and resting.

Investigator's Name(s): David H. Headrick, Bobbie Orr, Thomas S. Bellows, and Thomas M. Perring.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1 - December 31, 1994

Introduction of Natural Enemies Attacking *Bemisia argentifolii*

The objective of the present study is to increase the diversity of natural enemies through importation, mass rearing, and release of exotic parasitoids in agricultural, urban, and natural field sites in the Imperial Valley. In the first year of this three year project we introduced *Amitus bennetti* into the Imperial Valley. This parasite is native to the Caribbean and we have observed aggressive parasitism of silverleaf whitefly by this species in the laboratory and greenhouse.

Releases began in June of 1994 and to date we have released over 200,000 *A. bennetti* into the Imperial Valley. Beginning in August we began post-release evaluation for *A. bennetti* establishment. Leaf samples were collected from field sites (usually three to six leaves after visual inspection). We have recovered *A. bennetti* from two of the urban release sites. In agricultural sites no *A. bennetti* were recovered. Several sites adjacent to agricultural land which had weedy hosts were plowed or sprayed with herbicide, thus, no recoveries of parasitoids were made, except at one such site in Westmorland where recoveries were made from *Helianthus* sp.

Investigator's Name(s): Kevin M. Heinz[1], James R. Brazzle[2], & Charles Pickett[3].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: May - October, 1994.

Evaluations of Field Releases of *Eretmocerus* nr. *Californicus* in San Joaquin Valley, California Cotton

Surveys of silverleaf whiteflies and their natural enemies have been conducted throughout the southern and central San Joaquin Valley of California by University of California scientists in 1993 and 1994 (1994 results are detailed in the abstract provided by Godfrey et. al. elsewhere in this progress report). Their results indicated that while late season whitefly densities are high, overall percentage parasitism by indigenous *Encarsia* and *Eretmocerus* spp. was approximately 1.5%. Further, the data indicate the need for introducing exotic natural enemies if biological control is to be a component of a total whitefly management strategy for San Joaquin Valley, CA agriculture. Laboratory evaluations conducted by the authors on 14 different species or strains of *Bemisia* natural enemies identified two candidates (*Eretmocerus* nr. *californicus* collected from the Rio Grande Valley of Texas, and *Eretmocerus* sp. nov. of unknown origin but first identified from collections from College Station, TX) for subsequent field evaluation in cotton. Each of the *Eretmocerus* spp. was mass produced in facilities provided by the Biological Control Program of the California Department of Food and Agriculture and each was released into three different sites in the San Joaquin Valley during the summer, 1994.

Each site consisted of a 1/2 ñ 1/4 acre ëreleaseí and ëno-releaseí plot of unsprayed acala cotton. The three *Eretmocerus* nr. *californicus* release sites were a commercial cotton field in Bakersfield, CA, and research plots on the University of California Shafter Field Station (Kern Co, CA) and the University of California Agricultural Research Center in Kearney (Fresno Co., CA). The three *Eretmocerus* sp. nov. release sites were research plots at the Shafter Field Station, University of California Westside Field Station (Fresno, CA), and the University of California, Davis campus (Yolo Co., CA). Estimates of whitefly and parasitoid population densities were obtained from censuses of 50 5th mainstem node leaves collected from each site weekly for approximately 13 weeks. Late 4th instar *Bemisia*, parasitoid pupae, and all stages of predatory insects were used in the population censuses. To keep the parasitoid releases within the realm of economic reality (from the perspective of a cotton grower), a release trigger of >0.1 immature *Bemisia* per leaf and a cutoff of no more than three parasitoids per plant were used to limit parasitoid releases. Parasitoid releases were initiated once the trigger was exceeded and when discontinued once the cutoff was reach. Between these two thresholds, parasitoids were released as adults on a weekly basis according to their availability from mass culture.

Releases of both parasitoid species resulted in significant reductions in *Bemisia* populations in the release plots compared to the no-release plots. Average densities of whiteflies per leaf at the termination of the study were 20.84 in the *Eretmocerus* nr. *californicus* release plots and 71.29 in the associated no-release plots. Similarly, average whitefly densities per leaf at the termination of the study were 0.20 in the *Eretmocerus* sp. nov. release plots and 0.59 in the associated no-release plots. Because the whitefly densities in the plots used for *Eretmocerus* nr. *californicus* releases were significantly greater than the plots used for *Eretmocerus* sp. nov. releases, no between-species comparisons in ability to suppress *Bemisia* populations were possible. Densities of predators in the release plots were not significantly different from predator densities in the no-release plots. Hence, we conclude that the observed differences in whitefly densities were due to the activity of the introduced parasitoids.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January - December 1994.

Introductions and Evaluation of Exotic Parasitoids in Southwestern Deserts in 1994

To date, 8 non-native species or populations of *Eretmocerus* in culture at the Mission Biological Control Laboratory (MBCL cultures M92019, India: Padappai; M93005, India: Thirumala; M92027, Egypt: Cairo; M94002, Texas: College Station; M94003, Texas: Mission) and three species of *Encarsia* (*Enc. formosa* M92030, Egypt: Nile; M93003, Spain: Murcia; M92018, India: Parbhani) have been or are currently being evaluated in field cage trials for their efficacy against *Bemisia* in southwestern desert climates. Each non-native is compared against the dominant native parasitoid species, *Eretmocerus* sp. Evaluations are conducted in each of the major crops affected by whitefly: spring melons, cotton, and cole crops. This coming year, evaluations will also be done in alfalfa.

Four *Eretmocerus* (M92019, M93005, M94002, M94003) reproduced in field cages in the Imperial valley in cotton and melon trials; further studies of these species are underway. The population of *Encarsia formosa* from Egypt (M92030) had very low levels of reproduction in caged releases in 1993 and 1994, and subsequent generations were not observed. Evaluations of the other species have been recently inititated.

In addition to evaluations, inoculative releases of several species have been made at urban and selected agricultural sites in Imperial valley, Yuma, and Mexicali. Parasites were supplied by Mission Biological Control Laboratory and released as unemerged pupae . Releases of *Eretmocerus* (M92019, M93005, M94002 and M94003) were made during the fall of 1993; each release site will be surveyed for establishment and overwintering survival.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: June - September 1994.

Natural Enemies Associated with Silverleaf Whitefly in Hawaii

A natural enemy augmentation study was initiated in Hawaii in June 1994 using the whitefly parasitoid *Encarsia formosa* . The strain of *E. formosa* used had been reared on silverleaf whitefly for several generations prior to releases. Replicated augmentation plots were set up in a commercial two year-old eggplant planting in the Kahuku area on the island of Oahu. Adult female *E. formosa* were released five times over a six week period (6 June - 11 July 1994). Three release rates were employed: 5, 10 and 25 individuals per plant along the middle 2 rows of a 4 row 75 ft plot. An untreated check was also employed where no parasitoids were released. During the 7 weeks following the initial release, no *E. formosa* parasitized whitefly pupae were discovered nor were any *E. formosa* adults seen on collected foliage. In contrast, whitefly pupae parasitized by *Encarsia transvena* (Timberlake), *Encarsia nigricephala* Dozier, and *Eretmocerus* spp. were found in very low numbers in the plots. Predators that may have excerted some influence on the whitefly population surveyed included two predatory mites, *Phytoseiulus hawaiiensis* Prasad and *Amblyseius* sp. nr *tetranychivorus* (identifications provided by James McMurtry, University of California, Riverside) and the coccinelid *Curinus coeruleus*. The predatory mites were consistently found in research plots throughout the survey period. Laboratory observations indicated that the mites fed on the mobile first instar crawler stage of the whitefly. A significant curvilinear relationship was found between the log-transformed mean densities of predator mites and the mean densities of whitefly nymphs (independent variable) on a leaf. Once the whitefly density surpassed ca. 1,000 nymphs/50 cm^2, the association between whitefly and predator mite densities turned downward, suggesting that high densities of whiteflies were not favorable to the predator mites, perhaps due to an over abundance of sticky honeydew or the lack of crawlers to feed upon. Further studies will be conducted on the predatory mites to determine their biology when using sweetpotato whitefly as a prey item.

Investigator's Name(s): Walker A. Jones.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January - December, 1994.

Reproductive Biology of *Eretmocerus* sp. from Texas

Eretmocerus sp. (nr. *californicus)* is often the most important parasitoid of immature *Bemisia* in many crop and non-crop host plants in the Lower Rio Grande Valley of Texas, and thus is a major target for manipulation for enhanced biological control. Its biology has not previously been studied. The potential female fecundity and longevity were studied in the laboratory by exposing whitefly-infested sweetpotato leaves to individual female parasitoids every other day at 27°C until parasitoid death. The exposed leaves, rooted in hydroponic solution and kept in ventilated dishes, were held for progeny emergence.

Mean total fecundity per female (n = 15) was 585.6 progeny (range 72-797) over an average lifetime of 25.8 days (range 14-35 days), with 87.1% successful emergence. However, female progeny were produced for only the first seven days (range 1-10 days); males were subsequently produced daily until parasitoid death. Female progeny production for the first seven days averaged 85.3%. Previously mated females that apparently became sperm-depleted after 10 days did not remate when exposed to two, <2-day-old males for 48 hours. Unmated female parasitoids produced only male progeny. Newly emerged females mated within one hour after emergence. One, two, three, five, seven, and ten day old virgin females generally successfully mated. However, progeny production after mating at five or more days was significantly reduced.

Investigator's Name(s): Walker A. Jones[1] and T.S. Bellows, Jr.[2]

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - 1994.

A Simple Technique for Using Excised Leaves for Studying the Biology, Behavior and Interactions of Biological Control Agents of *Bemisia* spp.

Many types of experiments with silverleaf and sweetpotato whiteflies are difficult to conduct well because immatures are sessile throughout most of their life, and there is no artificial rearing system currently available. Many kinds of experiments such as temperature effects on natural enemies or behavior studies under microscopes frequently require that leaves with developing whiteflies be removed from plants. Various techniques are known and used to prevent or delay desiccation of whole or cut pieces of host leaves, but most alter normal vascular activity and thus can affect whitefly fitness. Although whitefly immatures may continue to develop, possible reduced fitness may significantly affect the outcome of experiments such as functional response of predators, biology of parasitoids and susceptibility to pathogens. We report a simple technique consisting of excised sweetpotato leaves in vials of hydroponic solution that keep whitefly immatures healthy yet allows many types of manipulative experiments to be conducted with relative precision while taking up little space.

In preliminary tests, excised leaves and terminal growth of several host plants were evaluated for survivability when place in a common hydroponic solution or in water. Most host plants such as *Brassica* varieties, cantaloupe, *Hibiscus* and cotton were unsatisfactory because they took up too much liquid or did not reliably survive excision. Terminal growing parts either kept growing, died or leaves failed to enlarge. Sweetpotato leaves in hydroponic solution proved most satisfactory for several reasons. In addition to serving as an excellent host for silverleaf whitefly, leaves nearly always survived cutting and transfer, and almost always rooted at the cut end of the petiole. They also withstand trimming to any size using scissors. The standard unit consists of an excised leaf placed in a floral aquapic containing hydroponic solution. Whitefly density and age (and settling location) are controlled by the condition, number and amount of time females are confined in clip cages. For studies of parasitoid or predator fecundity or where insects must otherwise be confined, the leaf/aquapic unit is placed in ventilated 150 x 25 mm plastic Petri dishes with filter paper bottoms. The pliable aquapic caps keep the solution from leaking out when resting horizontally in dishes. Leaves will usually keep quite well under fluorescent lights for at least one month.

This system has been used in several studies of parasitoids including development rate and daily fecundity. It was used to study several aspects of parasitoid behavior under binocular microscopes and videocameras where individually marked hosts had to be held in an incubator for progeny emergence. The system is also currently used for parasitoid culture maintenance in Texas, and current research there on whitefly pathogen and parasitoid interactions rely on this method. Leaves containing known stages and numbers of immatures have been used as sentinel hosts to obtain a relative measure of parasitoid foraging activity in field plot tests of both insecticides and fungal pathogens. Small colonies of whiteflies can also be conveniently maintained indoors where they are less susceptible to typical problems of greenhouse culture. A drawback to using these units for research is the obvious limitation of obtaining results that relate to sweetpotato as the host plant, and caution must be used when interpreting parasitism and predation if used as survey tools in other crops. Aquapics must be refilled every 2-4 days at about 25°C and 60% RH. Excessive root growth will cause more frequent refilling if not trimmed occasionally. Larger volume aquapics or custom made units could reduce refilling frequency. Generally, this method has been and continues to be very useful in obtaining data that would otherwise be less precise or more difficult to obtain by other techniques.

Investigator's Name(s): Walker A. Jones[1] and J.T. Monk[2].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January - December 1994.

Fate of *Bemisia argentifolii* Larvae Following Oviposition and Host Feeding by *Eretmocerus* sp.

The important whitefly parasitoid in south Texas, *Eretmocerus* sp. (nr. *californicus*) kills hosts by parasitization and host feeding. The potential host mortality rate attributable to host feeding is not known nor can host-fed whitefly immatures be specifically identified in field samples. Previous work demonstrated that the Texas *Eretmocerus* sp. spends about the same amount of time in host feeding behaviors as those devoted to oviposition behaviors. However, many hours of observation strongly suggests that these parasitoids feed for a long time on a small number of hosts compared to the number parasitized over a similar time span. The effect of feeding on hosts has not been documented. We also noted that oviposition behavior does not always yield successfully parasitized hosts. We observed and marked individual host immatures as to whether they were parasitized or fed upon by individual foraging female parasitoids. Oviposition was further classified as to whether or not females performed a post-oviposition "dance." Whitefly hosts were held and ultimately classified as to parasitized, unparasitized or dead due to unknown causes.

Preliminary results (96 observations) show that successful parasitism does frequently occur when oviposition behavior does not include the "dance", but most ovipositions that did include the dance behavior were successfully parasitized. A significant number of hosts in both oviposition categories died without producing identifiable parasitoid or whitefly development. All host-fed whiteflies died, appearing empty and dried out. The frequency of apparent ovipositions by individual parasitoids was much greater than that of host feeding.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January - December, 1994.

Insecticide Effects on Immatures of Native and Imported *Eretmocerus* spp.

Most crop hosts of the silverleaf whitefly in the Lower Rio Grande Valley of Texas are also attacked by other pests such as the boll weevil in cotton and lepidopterous pests in cole crops. Strategies for conserving or augmenting parasitoids to manage silverleaf whitefly in those affected crops will require information on how a variety of pesticides affect parasitoids and other natural enemies. Such knowledge is necessary so that selective chemicals can be identified, and parasitoid releases can be timed to enhance effectiveness.

We recently demonstrated that there were significant differences in responses of adult native and imported species of *Eretmocerus* and *Encarsia* among several insecticides having different modes of action. An *Eretmocerus mundus* culture imported from Spain demonstrated significantly greater survival than three other species when foraging on leaf residues of a variety of compounds. We report here the results of an initial trial to measure the survival of immature *E. mundus* and the common south Texas *Eretmocerus* sp. (nr. *californicus*) when cotton is sprayed with azinphos-methyl, buprofezin, bifenthrin, endosulfan, methyl parathion, thiodicarb or water. The *E. mundus* were supplied by USDA, APHIS, Mission Biocontrol Laboratory, Mission, TX.

Whitefly adults were confined in clip cages to five leaves each on 28 potted cotton plants. When the whiteflies were in the 2nd-3rd stages, one mated female parasitoid of each species was confined to each of 70 infested leaves. Four days later the infested leaves of half of the plants were sprayed to runoff with recommended rates of each insecticide. Eight days later the other half of the exposed larvae were identically sprayed.

Low rates of parasitism masked some potential differences between materials. Overall, survival was high for both parasitoid species sprayed as larvae and as pupae. Generally, young parasitoid larvae were most susceptible to buprofezin, but emergence was unaffected when sprayed just prior to emergence. Pre-emergent *E. mundus* were most susceptible to methyl parathion. Tests have been repeated under more rigorous methods and the results will be reported later.

Investigator's Name(s): Alan Kirk, Lawrence Lacey.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Foreign Exploration for Natural Enemies of *Bemisia tabaci/Bemisia argentifolii*

During 1994 foreign exploration for natural enemies of *Bemisia tabaci* sensu lato was conducted in Brazil (dry tropical), Thailand (dry tropical), Malaysia (humid tropical and humid montane), Israel (Mediterranean and desert), Italy (Mediterranean) and Spain (desert).

Collections from a broad diversity of host plants (crops and weeds) yielded populations of *Encarsia formosa*, *E. lutea*, *E. transvena*, *E. adrianae*, 4 *Encarsia* spp., and *Eretmocerus* spp., predatory coccinelids in the genera *Serangium*, and the following species of fungi: *Paecilomyces fumosoroseus*, *Verticillium lecanii* and *Aschersonia* spp.

A greenhouse based system of mist spraying was set up to apply fungi to whiteflies. The aims of this work are to evaluate the efficacy of fungi and the associations between fungi and insect parasitoids.

Since 1991 the EBCL team has been collecting natural enemies of *Bemisia tabaci/B. argentifolii* from various locations around the globe (Mediterranean Basin, Middle East, Western and Southeastern Asia and South America). Our principal client has been the USDA-APHIS Biocontrol Lab in Mission, Texas. Of the various colonies of natural enemies generated from our collections, colonies of 47 of these are currently maintained at the Mission Lab.

In addition to insect natural enemies, hundreds of isolates of fungi from whiteflies that were collected from around the world by EBCL have been deposited in the ARS Entomopathogenic fungal culture collection (ARSEF) in Ithaca, New York and at EBCL. These are being evaluated in the lab and field at EBCL and in the lab by cooperators in ARS Labs (Weslaco, Peoria, Ithaca), two INRA Labs in France, an EMBRAPA Lab in Brasilia and at Volcani Institute in Israel and the Dutch Floriculture Lab. Some of these isolates are exceptionally virulent and/or have increased tolerance to high temperature, UV-B, etc.

Investigator's Name(s): [1]Alan Kirk, Lawrence Lacey; [2]John Goolsby, Don Vacek; and [3]Mike Schauff, Steve Nakahara.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Drought Adapted Natural Enemies of *Bemisia argentifolii* from Thailand

Exploration in spring 1994 for natural enemies of *B. argentifolii* in Thailand coincided with a persistent severe drought. Parasitized populations of *B. argentifolii* from ten crop, eleven widely different weed species and two ornamental plants yielded,(host plants first); *Xanthium*, *Encarsia adrianae*, *Eretmocerus* sp.; Cucurbit, *Eretmocerus* sp.; *Cleome*, *E. adrianae*; *Heliotropium*, *E. adrianae*; *Chromolaena*, *Eretmocerus* M94036/40, Eggplant, *Eretmocerus* M94023/36/40*; Melon, *Eretmocerus* M94023/36/40*; Snakeweed, *E. formosa* M94051/92030/17**; Cotton, *Encarsia* sp. M94024***; Cotton, *Eretmocerus* M94040/36; Poinsettia, *E. transvena* M94041/47.

* 2 PCR patterns, one unique uniparental *Eretmocerus* sp.
** Similar PCR - patterns to Nile/Angelohori *E. formosa*
*** Unique banding pattern.

The host plant range and the whitefly natural enemy associations suggest that *B. argentifolii* in Thailand is not a recent arrival. Several parasitoid species are in culture at the Mission BCL and represent a source of natural enemies adapted to extremely dry conditions.

Investigator's Name(s): T. A. Knauf.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - 1994.

Control of Silverleaf Whitefly in Greenhouse Tomatoes with Naturalis-L

Naturalis-L is a biorational insect control product formulated by Troy Biosciences, Inc., of Phoenix, Arizona. The product is a conidial suspension of a naturally-occurring strain (ATCC 74040) of the insect-specific fungus, *Beauveria bassiana*. Naturalis-L, in its present liquid form, had been tested in the field for four years under a variety of crop production conditions and on a wide range of crops and insects and was extended an Experimental Use Permit in 1992 and again in 1993. As the second year of Experimental Use Permit studies came to an end, it became apparent that Naturalis-L was effective in controlling numerous insect pests without adversely affecting beneficial insects.

Naturalis-L had previously been used successfully for full-season insect control for three consecutive years in two commercial cotton crops and one spring cantaloupe crop. Control of whitefly (*Bemesia tabaci/Bemisia argentifolii*) had been demonstrated on numerous vegetables in Rio Grande Valley of Texas. When an experimental use permit was issued for Florida tomatoes, six commercial farms engaged in cooperator studies on their spring and fall tomato crops. These field studies demonstrated that Naturalis-L, when applied using best-coverage techniques, controls whitefly as well as the conventional insecticides currently in use in commercial production programs on the cooperating farms in these trials. When combined with conventional insecticides, Naturalis-L provided significant enhancement in control compared to insecticides used alone.

In 1993, some greenhouse cooperators had fully incorporated the product into their ornamentals program and had begun to ship "clean" plants for the first time in years.

Finally, in late 1993 and through 1994, under an expanded E.U.P., trials on greenhouse tomatoes were initiated in cooperation with Hydrogardens, Inc., of Colorado Springs, CO. Commercial growers served as cooperators who initiated small scale trials in areas and houses where whitefly infestations were severe. A variety of sprayers, schedules, insecticides, and rates were utilized in these trials, and results varied accordingly.

The cooperators monitored the effects of Naturalis-L on whiteflies. All expressed leaf samples to the Troy Biosciences lab in Phoenix, Arizona for counts of eggs and immatures. Some performed on-site counts of adult whiteflies.

Overall, where Naturalis-L was applied using best coverage techniques on a 5-7 day schedule and at rates of 1/2 to 1 oz./gal., control of whitefly was achieved. Use with other chemicals and insecticides in a tank mix or use with insecticidal smokes can facilitate control. However, use of Naturalis-L alone at the recommended rate and timings provided whitefly control comparable to that achieved with commercial insecticides.

Investigator's Name(s): T. A. Knauf.

Affiliations & Locations: Project Leader, Troy Biosciences, Inc., Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - 1994.

Control of Whiteflies and Mites in Ornamentals With Troy Biosciences EXP 7744

Troy Biosciences EXP 7744 is a Naturalis insect biocontrol product formulated with a strain of the insect-specific fungus, *Beauveria bassiana* (ATCC 74040). In 1992, under an Experimental Use Permit, EXP 7744 was evaluated for control of whitefly (*Bemisia tabaci/Bemisia argentifolii*) in Texas and Florida greenhouses. Twelve studies were completed with nine cooperators. Each study was supervised by a professional entomologist or horticulturist who coordinated trial installation, product applications, and data acquisition. The results of those studies indicate that EXP 7744, whether applied alone or with conventional insecticides, controlled whitefly immatures and adults under a wide variety of conditions.

In 1993, the E.U.P. was renewed and studies utilizing EXP 7744 continued to yield information on product efficacy under actual production conditions. Eleven trials were implemented. While several trials remained closely supervised by consultants, others were allowed to be conducted by the growers themselves--as would be the case upon full registration and commercialization. Varying degrees of efficacy were observed due to the new variables which were introduced through direct grower participation. Generally, where EXP 7744 was applied according to instructions and with good underleaf coverage, the product continued to control whitefly adults and immatures on a par with the best programs utilizing conventional insecticides. When applied in combination with conventional insecticides, significant enhancement of control was observed in trials using best-coverage techniques.

In 1994, the E.U.P. was expanded to include nursery shadehouses and lathhouses in Texas and Florida. Cooperators in other states also participated on a limited and closely-supervised basis. In all, 21 trials were implemented with 17 cooperators. Studies in 1994 reinforced outcomes received in the previous two seasons and provided additional information on insect control strategies utilizing EXP 7744.

EXP 7744 controlled whitefly eggs, immatures, and adults under a wide spectrum of commercial conditions. Mites (*Tetranychidae*) were also controlled where the product was applied at the recommended rates and intervals using best coverage methods. Product performance was best where trials were conducted by professional consultants and superior spray coverage strategies were used.

Troy Biosciences EXP 7744 may be applied alone or combined with conventional insecticides. In either case, thorough coverage which treats leaf undersides is essential for control of whiteflies and mites. Where coverage is thorough and application timing is correct, excellent control may be expected with EXP 7744.

Investigator's Name(s): T.A. Knauf and J.E. Wright.

Affiliations & Locations: Troy Biosciences, Inc., Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - 1994.

Evaluation of Naturalis-L for Control of Whitefly and Other Cotton Insects A Synopsis of 1993 and 1994 Trials in Arizona, Texas, Louisiana, and Mississippi

Naturalis-L is an insect biocontrol product formulated as a conidial suspension of *Beauveria bassiana* (ATCC 74040). It was evaluated for control of cotton insects both alone and as a component in Integrated Pest Management (IPM) programs. The effect on target and beneficial insects was monitored. Target insects included sweetpotato (silverleaf) whitefly (*Bemisia tabaci/Bemisia argentifolii*), boll weevil (*Anthomous grandis*), fleahopper (*Pseudatemoscelis seriatus*), and tarnished plant bug (*Lygus lineolaris*). Where conditions permitted proper applications timing, best spray coverage approaches were used, and weather was not inclement, Naturalis-L biorationals provided effective control of cotton insects either alone or in combination with conventional insecticides in an IPM approach. Where yields were taken, Naturalis-L treatments and IPM programs containing Naturalis-L provided cotton yield protection that did not differ significantly from that provided with the standard insecticide program. Yields tended to be highest where Naturalis-L was used in an IPM program. It was likely that beneficial insects spared by Naturalis-L were also responsible for control of insects not known to be impacted by *Beauveria bassiana.*

This may be the only insect control program suitable for use in some environmentally-sensitive areas. As concerns for the environment continue to grow, regulation may usher in a time when biorational insect control will be the only available strategy. The U.S.E.P.A. is emphasizing safer alternatives to conventional insecticides. Naturalis-L is considered such an alternative. It is effective, and it does not impact test animals, aquatic organisms, beneficial insects, or applicators. It does not persist in the environment for more than 72 hours. Therefore, it is a promising candidate for the new "safer" pesticide status under discussion by E.P.A.

However, the best use of Naturalis-L, particularly against whitefly, plant bug, and fleahopper may be with its use as a component in an IPM program which utilizes strategically-timed and reduced-rate applications of conventional insecticides in tandem with biorationals. Future work will further refine and reference the effect of Naturalis-L biorationals on a wider range of insects which damage economically important crops. *Beauveria bassiana* (ATCC 74040) formulation variations for specific insects and crops and new "safer" insect-specific organisms and products are currently in the research and development process at Troy Biosciences, Inc.

Investigator's Name(s): Lawrence Lacey[1], Alan Kirk[1], Alain Vey[2], Karel Bolckman[2], Guy Mercadier[1] and Claire Vidal[1].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

The Effect of Host Plant on Activity of *Paecilomyces Fumosoroseus*

Field trials of *Paecilomyces fumosoroseus* in glasshouse crops in Europe suggests an effect of host plant on the efficacy of the fungus against *Bemisia argentifolii*. When cucumber and tomato crops were sprayed with suspensions of *P. fumosoroseus* under identical conditions, the fungus was more efficacious on cucumber; development of the fungus on whiteflies was invariably faster on the cucumbers. To investigate this phenomenon on a quantitative basis, several plant species were evaluated for enhancing or limiting effects on *P. fumosoroseus* against *B. argentifolii* under laboratory conditions. Plant species included cabbage, tomato, *Ipomoea*, eggplant, hibiscus, cotton and squash. Leaf disks that were infested with mixed instars of the whitefly were maintained on Knops' medium and sprayed with a discriminating dosage, 175 conidia/mm^2, of *P. fumosoroseus*, incubated for 48 hours at 24°C first in saturated humidity and then at 50% RH. The specimens were then fixed and processed for observation in a scanning electron microscope. Bioassays were also conducted on leaf disks of the same species that were infested with second instar nymphs, incubated in saturated humidity for 24 hours and then at 50% RH at 24°C for an additional six days before assessing mortality.

Scanning electron micrographs of spore coverage on nymphs reveal a highly irregular distribution of spores that is not necessarily related to plant species. Spore distribution on water agar that was sprayed with the same concentration of fungal spores was considerably more regularly spaced. No significant differences in mortality of nymphs on the leaf disks that survived in good shape was observed (*Ipomoea*, cabbage, hibiscus and tomato). A major drawback to this assay method was the rapid deterioration of eggplant and squash leaves and to a lesser extent, cotton and tomato leaves.

A myriad of factors can influence the coverage of conidia on leaf surfaces and their subsequent activity against *B. argentifolii*. Those conditions that could not be controlled were the precise age of individual nymphs and the differential survival of leaf disks on Knops' medium. The rate of germination was highly variable from nymph to nymph on the same leaf under identical conditions. Whether this was due to the physiological state of the nymphs or some other factor is not known at this time, but warrant further investigation. Development of assay systems that enable good survival of host plants under the conditions required for the objectives of our tests will be the immediate goal of research in 1995.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: September, 1993 - September, 1994.

Foreign Exploration and Evaluation of Some Natural Enemies of *Bemisia argentifolii* from Southeast Asia

A collaborative project on biocontrol of the silverleaf whitefly, *Bemisia argentifolii*, was initiated between the USDA-ARS, Biological Control of Pests Research Unit and Asian Vegetable Research and Development Center (host scientist N. S. Talekar) in Taiwan (funded by USDA-Office of International Cooperation and Development). Natural enemies of the silverleaf whitefly, *Bemisia argentifolii* were collected from the Philippines and Taiwan on two separate occasions in December, 1993 and March, 1994. Collectors were S. C. Legaspi, R. I. Carruthers, T. J. Poprawski and C. P. Moomaw (Texas A&M). In the Philippines, parasites, predators and pathogens were collected from Laguna and Cavite (Central) and Benguet (North). The plant hosts were cassava, eggplant, guava, hibiscus, sweetpotato, potato, tomato, pole bean, squash, sunflower, salvia and hollyhock. Three species of fungal pathogens collected were identified to be *Paecilomyces fumosoroseus*, *Fusarium coccophilum* and *Beauveria bassiana*. The parasites collected were identified in the laboratory as *Encarsia sp. nr. transvena, Encarsia lutea*, and *Eretmocerus* sp. In Taiwan, parasites were collected from poinsettias, soybean, tomato, eggplant, cucumber and a species of herb from the greenhouses and fields in Tai-Chung (Central), and Shan-hua, Tao-Yuan and Ping-Tung (South). The predator collected from an eggplant field was identified to be *Illeis koebele*. From a total of 6 shipments sent to J. Goolsby (USDA-APHIS, Mission, TX), 2 species of *Encarsia* and *Eretmocerus* from Taiwan and one species of *Encarsia* from the Philippines are currently being reared at the APHIS quarantine facility in Mission, TX. The three species of pathogens collected from the Philippines are kept at the Biological Control of Pests Research Unit, ARS in Weslaco. Samples of parasitized whiteflies were sent to D. Vacek (MBCL-APHIS, Mission, TX) for genetic analysis of the parasite species. Voucher specimens of the parasites were sent to M. Rose, G. Zolnerowich, and J. Woolley (Texas A&M) and to M. Shauff (USDA Systematic Entomology Lab.) for taxonomic identification. Samples of the whitefly collected were sent to J. Brown (U. Arizona) and R. Gill (California Dept. of Food and Agriculture) for genetic, enzymatic and morphological identification and comparison to populations found in the U.S.

One of the parasites collected from Taiwan, an *Eretmocerus* sp., was evaluated for efficacy against the silverleaf whitefly in the quarantine facility at Mission, TX. Parasitism of one of the *Eretmocerus* sp. was studied on different plant hosts such as poinsettias, hibiscus, cucumbers, cantaloupes and eggplant. Two female parasites were released in cages with 3-5 potted plants consisting of two different plant hosts. The parasites were kept in the cage for 48 hr, after which the plants were removed. After 10-14 days, the numbers of parasitized and unparasitized third and fourth instar *Bemisia argentifolii* per potted plant were counted. Preliminary results from this study showed variable rates of parasitism across the different plant hosts. Percentage parasitism was lowest in poinsettias 0.2% for 3rd instars (20/9858) and 0.69% (11/1598) in fourths. Whitefly parasitism was highest in hibiscus with 1.4% (21/1513) in 3rds and 16% (102/638) in 4ths. In collaboration with J. Goolsby, the remaining colonies of parasites are currently being evaluated together with other exotic parasitoids still in quarantine (possibly 19 colonies with distinct DNA banding patterns) collected from other parts of the world. We are measuring parasitism on melon host plants to evaluate biological control potential for field release in the Lower Rio Grande Valley of Texas.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Susceptibility of *Delphastus Pusillus* (Coloptera: Coccinellidae), a Predator of *Bemisia argentifolii* (Homoptera: Aleyrodidae), to Some Selected Biorational Insecticides

Susceptibility of all developmental stages of *Delphastus pusillus* (LeConte), a predator of *Bemisia argentifolii* Bellows & Perring, to some selected biorational insecticides was studied in laboratory. The biorational insecticides used were: Sunspray Ultra Fine Oil (a mineral oil; Safer Inc., Newton, CA), 0.2% (vol./vol.); M-Pede (an insecticidal soap, 49% potassium salt of a naturally derived fatty acid; Mycogen Corp., San Diego, CA), 0.5% (vol./vol.); extract of *Nicotiana gossei* Domin (an acylsugar), 0.02% (w/vol.). Bifenthrin (Capture 2EC, pyrethroid; FMC Corp., Middleport, NY), 0.048 g (AI)/I, was tested for comparison and water (reverse osmosis, 7 ppm dissolved solid) as a control.

In order to distinguish the stages of *D. pusillus* larvae, body lengths and head (capsule) widths of all developmental stages were measured. Head width was a good indicator of developmental stage, whereas body length was not. For convenience, however, we separated the larvae into two groups, small (first and second instars) and large (third and fourth instars).

Bifenthrin was toxic to all developmental stages of *D. pusillus*. Mortality responses to bifenthrin of adults, eggs, small and large larvae and pupae were 97.6, 100, 97.1, 95.0, and 66.1%, respectively. Larvae assumed an arc-shaped attitude on bifenthrin-treated leaf surfaces with the two extreme ends of the body touching the leaf surface and mid-section bent upward. Among the biorational insecticides, M-Pede was toxic to small larvae (85.2%) and large larvae (66.0%), but not to adults (1.4-3.3%), eggs (14.4%) or pupae (16.3%). Sunspray oil some effect on eggs (30.4%), but less on small larvae (12.7%), large larvae (11.4%) and pupae (11.3%). *N. gossei* extract did not significantly affect any stage of beetle (7.3% adults, 7.5% eggs, 13.7% small larvae, 7.6% large larvae, 12.3% pupae). Mortality of *D. pusillus* adults were not significantly different when leaves were dipped in insecticide solutions or sprayed with 2-ml insecticide solution using the Potter Spray Tower.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994.

Susceptibility of *Encarsia Pergandiella* Adults (Hymenoptera: Aphelinidae), Parasitoid of *Bemisia argentifolii* (Homoptera: Aleyrodidae), to Some Selected Insecticides on Tomato and Sweet Potato Leaves

Residual toxicity on glass vial and leaf surfaces and repellency of some selected biorational insecticides to *Encarsia pergandiella* Howard, a parasitoid of *Bemisia argentifolii* Bellows & Perring, were determined in laboratory. The biorational insecticides used were: Sunspray Ultra Fine Oil (a mineral oil; Safer Inc., Newton, CA), M-Pede (an insecticidal soap, 49% potassium salt of a naturally derived fatty acid; Mycogen Corp., San Diego, CA), Margosan-O (neem extract, 0.25% azadirachtin; Grace-Sierra, Milpita, CA), *Nicotiana gossei* extract (an acylsugar) and a synthetic acylsugar (#5691)(USDA, ARS, SAA, Athens, GA). Bifenthrin (Capture 2EC, pyrethroid, FMC Corp., Middleport, NY) was also tested and RO water (7ppm dissolved solid) was used as a control. The concentrations used were: bifenthrin, 0.048 g (AI)/1 for toxicity bioassay, and 0.024, 0.048 and 0.096 g (AI)/1 for repellency tests; Sunspray oil, 0.05% (vol./vol.) for toxicity bioassay and 0.1, 0.2 and 0.4% for repellency tests; M-Pede, 0.5% (vol./vol.) for toxicity tests and 0.25, 0.5 and 1.0% for repellency tests; *N. gossei* extract, 0.02% (wt./vol.) for toxicity bioassay and 0.01, 0.02, 0.04% for repellency tests.

Bifenthrin was the most toxic insecticide tested to *E. pergandiella* adults when bioassayed in glass vials (96.2%), followed by Sunspray oil (93.7)%. Mortality response to treatments of M-Pede, Margosan-O (neem extract), *N. gossei* extract and the synthetic acylsugar was low (16.0, 7.9, 8.1 and 7.8%, respectively), and not significantly different from water control (5.8%) except for M-Pede. Leaf surface bioassays produced similar results except for the response to Sunspray oil and M-Pede which was significantly less than in glass vial bioassays (mortality = 48.6 vs 93.6% and 5.6% vs. 16.0%, respectively). Exposure to leaf residues of bifenthrin, Margosan-O, *N. gossei* extract and synthetic acylsugar gave 100%, 11.0, 10.1 and 6.5%, respectively. Response to residues from sprayed vs. leaf dip applications of bifenthrin was similar (93.7% vs 100%), whereas Sunspray oil residues on leaves caused significantly less mortality (43.4% vs. 13.3%) when sprayed.

Repellency tests showed that lowest parasitism rates occurred on infested tomato leaves treated with low rates of bifenthrin (0.5-2.2% at 0.005-0.02%(AI) rates), followed by Sunspray oil (0.9-2.4% at 0.1-0.4% rates) and M-Pede (1.1-3.6% at 0.25-1.0% rates), while treatment with *N. gossei* extract resulted in even gave higher parasitism (15.3-32.9% at 0.01-0.04% rates) than water control (15.5%). Repellency tests on sweet potato leaves gave similar results. Parasitism was lowest in the treatments of bifenthrin (1.6%), followed by Sunspray oil (2.9% at 0.2% rate), Margosan-O (3.7% at 0.006%[AI] rate). Parasitism in the treatments of M-Pede (6.5%) and *N. gossei* extract (9.7) was not different from water control (9.9%).

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July - October, 1994.

Parasitism of Silverleaf Whitefly in Soybean Isolines Varying for Foliar Pubescence

In 1993 and 1994, 3 near-isolines of soybean varying for foliar pubescence were evaluated under field conditions for resistance to silverleaf whitefly (described in detail in McAuslane et al., Section E, this volume). Peanut was also tested in the field experiment to determine whitefly preference and to see whether soybean could be used as a trap crop for whiteflies in peanut. One soybean near-isoline was glabrous (D90-9216, PI 561573), one was pubescent (D75-10169) with 2.94 ± 0.17 hairs/mm^2 (mean ± SEM), and the third was hirsute (D90-9220, PI 561572) with 17.42 ± 1.35 hairs/mm^2. 'Sunrunner' peanut was glabrous.

In both years, *Encarsia nigricephala* Dozier was the most abundant parasitoid parasitizing silverleaf whitefly (68% of total parasitism in 1993 and 75% in 1994). *Encarsia pergandiella* Howard was the next species most commonly reared from parasitized whiteflies (22.6% in 1993 and 15.1% in 1994). *Eretmocerus* nr. *californicus* Howard accounted for 8.5% of parasitism in 1993, and 5.7% in 1994, and *Encarsia transvena* Timberlake accounted for 0.9% parasitism in 1993 and 4.1% in 1994.

Different parasitoid species were more common on different soybean genotypes. In 1993, *E. nigricephala* accounted for a significantly greater proportion of total parasitism on peanut and on glabrous soybean than on hirsute or pubescent soybean. *E. pergandiella* and *E.* nr. *californicus* accounted for more parasitism on the hairy soybean genotypes than on either peanut or glabrous soybean. In 1994, proportion parasitism among the four genotypes did not differ signficantly for *E. nigricephala* or *E.* nr. *californicus*, but *E. pergandiella* again accounted for a significantly greater proportion of total parasitism on hirsute and pubescent soybean than on glabrous soybean or peanut. *E. transvena*, like *E. nigricephala* in 1993, accounted for significantly more parasitism in peanut and glabrous soybean than on hairy soybean genotypes.

In 1994, no significant differences in total parasitism were observed among the 3 soybean isolines and peanut. This is in contrast to 1993 when a significantly greater proportion of fourth instars were parasitized on peanut and on glabrous soybean than on hairy soybean genotypes. This finding may have been due to the fact that *E. nigricephala* became drastically male-biased halfway through the 1994 season and total parasitism dropped to 40% from a high of 70%.

In conclusion, the whitefly parasitoids common in northcentral Florida appear to have either different parasitization efficiencies or different microhabitat preferences that are based on the foliar pubescence of their whitefly hosts' host plant.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - December 1994.

Evaluation of *Eretmocerus* nr. *Californicus* ex. Arizona for Augmentative Biological Control of Silverleaf Whitefly on Field and Greenhouse Crops

The mass-rearing of *Eretmocerus* sp. ex. Arizona at the University of Arizona north campus has allowed us to produce large quantities of wasps viz. millions per week, for evaluation against silverleaf whitefly in commercial plant production systems (CIBA Bunting Ltd., U.K., is sponsoring the rearing). We have shipped parasitoid pupae to cooperators in various states for further evaluation. In 1993, a total of 750,000 wasps were sent to L.S. Osborne (Univ. of Florida, Apopka: greenhouse hibiscus), J.R. Baker (North Carolina State Univ., Raleigh: greenhouse poinsettias), J.P. Sanderson (Cornell Univ., Ithaca: poinsettias) and M.S. Hunter and M. Rose (Texas A&M Univ., College Station: systematics). In 1994, three million wasps in total went to L.S. Osborne, J.P. Sanderson and G.W. Ferrentino (same projects), M.F. Antolin (Colorado State Univ.: genetics), M. Hoddle and R.G. van Driesche (Univ. of Massachusetts: poinsettias), N.M. Gruenhagen and T.M. Perring (Univ. of California, Riverside: behavior), S. Moody and S.D. Eigenbrode (Univ. of Arizona, Tucson: parasitoid-plant interaction). Production of *Bemisia* parasitoids in high numbers is thus feasible and extensive research of their ecology and applicability is ongoing.

The crops for which we examined the potential use of *Eretmocerus*, were cotton, melons and greenhouse poinsettias:

<u>Cotton</u>: we demonstrated that *B. argentifolii* can be controlled by *Eretmocerus*, at least in field cages, and that a release rate of 4 to 32 parasitoids per plant is required. Releases of high numbers of parasitoids in field plots were less effective; parasitism and whitefly density did not differ between release and control plots. A possible explanation is the immigration of adult whiteflies during June and July. To counteract this strong increase in adult whiteflies, we applied an oil solution to the upper canopy, because adults mainly reside in the top of the plants. Most whitefly nymphs and pupae were located in the center of the plant; parasitoids were released at the bottom. The integration of augmentative biological control with oil treatments was examined on a 3.5 ha field plot in the Imperial Valley in 1994. Although reasonable levels of parasitism were reached, whitefly levels were unacceptably high and yield was low (1.3 bails per acre). Given the rates of parasitoids needed and their current costs, and the whitefly pressure in low desert agriculture, we conclude that augmentative biological control of *B. argentifolii* in cotton is not effective nor economically feasible in the Southwest.

<u>Melons</u>: we conducted a open field release and a replicated cage trial in 1994. On 2.5 ha of cantaloupes 125,000 wasps were released. A small population was established and parasitism went up to 13.7%. Subsequently, whitefly levels increased dramatically toward the end of July (about 60 times between July 14 and August 2). In the cage experiment (July - September), about 1,000 wasps were released per cage. Parasitism in the release cages went up to 21.5%, whereas in the control cages it stayed at 0% (sample September 26). Whitefly densities were not significantly different between treatments: 1.4 REN and 1.3 REN per 4 cm^2 leaf disc, respectively. These results indicate that this *Eretmocerus* sp. has not a major impact on whiteflies in cantaloupes.

<u>Poinsettias</u>: life table studies by M. Hoddle, J.P. Sanderson & R.G. van Driesche showed that *Eretmocerus* caused 99.1% mortality in *B. argentifolii* cohorts on glasshouse poinsettias (release rate was 3 females/plant/week). Other greenhouse and cage evaluation studies in the Northeast have confirmed that *Eretmocerus* is a biological control candidate against whiteflies on commercial poinsettias. Studies on the use of inundative releases in poinsettias in southern California are underway.

Investigator's Name(s): Ru Nguyen, F.D. Bennett.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1990 - 1994.

Introduction and Establishment of *Eretmocerus* sp. (HK) (Hymenoptera: Aphelinidae), a Parasite of *Bemisia argentifolii*, in Florida

The sweetpotato whitefly, *Bemisia tabaci*, was known in Florida in early 1900 by Quaintance and *Aleyrodes inconspicua* until 1957. It did not create any serious damage to Florida agriculture until 1987. That year a severe outbreak occurred on poinsettias in nurseries and then on tomatoes in southwest Florida. This strain of sweetpotato whitefly was referred to as *Bemisia tabaci* strain B and then *B. argentifolii* Bellows & Perring. Efforts to develop a satisfactory IPM solution to the problem was initiated in 1990 by the introduction of exotic parasites to Florida.

Eretmocerus sp. (HK) was collected in Kowloon Park, Hong Kong on July 13, 1992 by F. D. Bennett. At first the parasite was cultured in plastic cylinders in the Quarantine Laboratory, Division of Plant Industry, Gainesville. *Eretmocerus* sp. (HK) is a thelytokons species and has a high rate of reproduction. The permit for field release was obtained on December 10, 1992, and parasites were mass reared on hibiscus infested with *B. argentifolii* in a greenhouse.

From March 1993 to May 1994, approximately 480,000 *Eretmocerus* sp. (HK) were released in Alachua, Marion, Volusia, Orange, Hillsborough, Polk, St. Lucie, Palm Beach, Collier and Dade counties in Florida. They were released in areas some distance from sprayed fields. Some were also released in unsprayed hibiscus and poinsettia plots in Homestead (Dade Co.), Boynton Beach (Palm Beach Co.), Ocala (Marion Co.) and Gainesville (Alachua Co.) to study the ability of parasite establishment in nearby sprayed areas in commercial nurseries. The parasite was recovered from the field about 3-4 weeks after initial releases and suppression of sweetpotato whitefly occurred at several locations. Hibiscus and poinsettia infested with *B. argentifolii* parasitized with *Eretmocerus* sp. (HK) were shipped to many retail stores, and sold in Florida and several other states.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1993 - 1994.

Preliminary Results on the Efficacy of *Encarsia Pergandiella* (Hyménoptera: Aphelinidae), in the Biological Control of *Bemisia tabaci* (Homoptera: Aleyrodidae)

During the first regional survey (Provence-Alpes Maritimes) of indigenous parasitoids attacking *B. tabaci* in greenhouses and open field habitats, the parasite *Encarsia pergandiella* was systematically recovered. It was therefore interesting to test its potential as a bio-control agent under controlled conditions, before thinking of introducing exotic species.

An experimental plan was carried out on spring tomatoes in order to define the possibilities and the conditions for biocontrol of *B. tabaci* using *E. pergandiella.*

Artificial infestation of adults of *B. tabaci* newly emerged was carried out at the end of March 1993 at a rate of 10 adults/tomato plant. The greenhouse (area 120 m^2) contained 200 plants arranged in 4 lines of 50. The adult population of the pest was studied in order to identify the levels preferentially colonized by the adults, these a few weeks later were examined for larval density and the efficacy of parasitization.

E. pergandiella was released 3 weeks later after artificial infestation of adults of *B. tabaci* at a rate of 4 parasitoid adults/adult white fly a the time of initial infestation, with a distribution in favor of females (1 male/20 females).

The first generation of *B. tabaci* preferred mature leaves for oviposition, situated more or less in the first floral bouquet. The second generation, returned to the older leaves previously infested and infested new leaves higher up.

The first check on the efficacy of *Encarsia pergandiella* was carried out on the first generation of *B. tabaci.* The percentage parasitism was higher than 50% and the structure of the parasitized population was mainly composed of healthy larvae and nymphs of *E. pergandiella* (92.2%). The check on the efficacy of the parasitoid on the second generation of whitefly showed a reduction in percent parasitism (44.1%), accompanied by an increasing number of healthy larvae and nymphs of the parasitoid (63.6%), a significant increase in hyperparasitized larvae (19.5%) and the appearance of parasitoids killed by repeated hyperparasitism (11.6%). A very large proportion of the hyperparasitized larvae were found on the leaves having already carried the first generation of whiteflies.

In this experiment where *E. pergandiella* was released at a rate of 4 to 1 with a strong proportion of virgin females, the primary percent parasitism was excellent in the first generation, very discouraging in the second generation as it was reduced by rising hyperparasitism. New experiments will be carried out with a different level of *E. pergandiella* sex ratio.

Investigator's Name(s): William Roltsch[1] and Charles Pickett[2].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: February to October 1994.

Release and Establishment of Two New Parasitoid Species in Imperial Valley

Two species of *Eretmocerus* have been received from USDA-APHIS, Mission Biological Control Laboratory. Mass reared at CDFA greenhouse facilities in Sacramento, 10 shipments of #M94003 (*Eretmocerus* species native to Mission, TX) were received and released in CDFA refuge field plots (see companion abstract for plot details) in Imperial Valley from April through June. Releases were made in 1 x .7 x 1m cages left in place for three days over collard. In addition, multiple releases were made in cages that were left in place for 6 weeks. Collard in refuge plantings was considered to be a favorable site for evaluation because native *Eretmocerus* parasitism is extremely low on these plants. No difference in percent parasitism between release and check plants occurred. A total of 25,000 parasites were released.

The second species released was #M94002 (bi-colored *Eretmocerus* species from College Stn, TX). It was first received in the last week of July and releases were made through October. Releases were made on 12 dates in 1 x .7 x 1m cages that were located on kenaf. It was the only available refuge plant at that time. Whitefly populations were abundant and so was parasitism by the native *Eretmocerus* species. After seven weeks following first release, parasitism in all cages was approximately 70%, and approximately 50% of the parasitoids were the bi-colored *Eretmocerus*. These results suggested that this species did well under strong competition by the native species on kenaf, and it did well under very high summer heat. Unfortunately, this species has been nearly undetectable outside of the release cages, even though equal numbers were released on plants immediately outside of the cages. A total of 65,000 parasites were released.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: September 1993 to October 1994.

Silverleaf Whitefly Natural Enemy Refuges in the Imperial Valley

Natural enemy refugia grown throughout the year are being evaluated in the Imperial Valley for their potential in building and maintaining populations of silverleaf whitefly (SLWF) parasitoids and predators. Plots consist of two rows of refuge plants alternating with 20 rows of crop (melon, cotton or broccoli). Refuge plantings occur twice each year at each field site; the first in approximately late February (interplanted sunflower, collard, kale and kenaf) and the second in late September (interplanted sunflower, kale and collard). Two refuge plots (2 acres each) and corresponding check sites are being evaluated at the USDA field station in Brawley, whereas one refuge plot (5 acres) and check site are present at a second farm site (organic) in southern Imperial County.

Native *Eretmocerus* nr. *californicus* parasitism on sunflower was 15% in January, 15-30% in February, and built up to approximately 60% by mid-March. It appears that native *Eretmocerus* densities decline through the winter months even on plants such as sunflower, upon which it commonly achives high levels of parasitism during other times of the year. During late summer through fall, kenaf provided an exceptional habitat for building large populations of this parasite, with a sustained level of parasitism well over 50%. This is at a time when cotton is being terminated and fall crops are being initiated. Unfortunately, the potential impact of this <u>native</u> parasite species' is highly constrained by its varied performance among SLWF host plants. Of particular significance, are its low to moderate percent parasitism on cantaloupe (up to 30%) and low levels of parasitism on colecrops (usually under 5%). Underscored by this work is the need for establishing new parasitoid species capable of performing well on a wide range of SLWF host plants. Parasite introductions are being conducted in the refuge plantings, as outlined in our companion abstract.

New plants are being screened for their potential as refuge plants. Roselle (*Hibiscus sabdariffa* var. *sabdariffa*) is closely related to kenaf [*Hibiscus cannabinus*]. Initial findings indicate that Roselle provides a highly favorable environment for parasitoids. This plant may be a valuable alternative to kenaf because of its short height and slender branches, thereby making it an easier refuge plant component to manage.

Regarding SLWF predators, *Geocoris punctipes* and *G. pallens* are among the most common, exhibiting a sustained presence on cantaloupe, cotton, and alfalfa. Although *Geocoris* populations are supported by refuge plants, the contribution to overall *Geocoris* activity by these refuge plantings remains unclear.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: June - November 1994.

Abundance of Parasitoids of *Bemisia argentifolii* in Sweetpotato

A survey of the parasitoids of *Bemisia argentifolii* was resumed at five coastal South Carolina sweetpotato field locations (Beaufort, Edisto Island, Johns' Island, Charleston, and McClellanville, SC). Yellow sticky cards were placed in sweetpotato fields (transplanted in June) and replaced weekly starting in early July and continued through 1 November. Additional samples of leaves were taken weekly and returned to the laboratory for parasitoid emergence. Except for a pre-transplant herbicide, no other pesticide was used on the crop. Whitefly infestation was low relative to the past two years. This may be related to the frequent and unusually heavy volume (76.4 cm) of rainfall from July through October. Overall abundance of whitefly parasitoids was low as compared with the previous year. Since 1992, at least three species of *Encarsia* (*E. pergandiella*, *E. nigricephala*, and *E. strenua*) and *Eretmocerus californicus* were recovered from coastal South Carolina. An additional parasitoid of *B. argentifolii*, *Signophora sp.*, was recovered in 1994. Parasitoid abundance varied over time, and was highest in September and October. In a laboratory test, the whitefly was more readily captured on sticky cards as compared with *E. pergandiella*, the only parasitoid tested in the laboratory. After 16 hours, ca. 25% more of the cohort of the whitefly was captured as compared with the cohort of *E. pergandiella*.

Investigator's Name(s): Alvin M. Simmons.

Affiliations & Locations: USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July - November 1994.

Parasitoids of *Bemisia argentifolii* in Vegetable Crops With and Without Lorsban

Abundance of parasitoids of *Bemisia argentifolii* were observed in four vegetable crops (tomato, cantaloupe, collard, and cucumber) treated with Lorsban as compared with plots that were not treated. During the study, the only pesticide used was a pre-emergence herbicide. Yellow sticky cards were set up and replaced weekly. The number of *B. argentifolii* and the number of its parasitoids per sticky card per crop per week were determined. Overall populations of *Bemisia* at the location was less abundant as compared with populations in 1992 and 1993. This may be related to the unusually high quantity (76 cm) of rainfall in the Charleston area in July, August, September, and October. In a laboratory study, *B. argentifolii* and *E. pergandiella* were caught on a section of sticky card in dissimilar proportions; the whitefly was more readily captured as compared with *E. pergandiella*, the only parasitoid tested in the laboratory. After 16 hours, ca. 25% more of the cohort of the whitefly was captured on the sticky card as compared with the cohort of *E. pergandiella*. In the field, parasitoids continued to be captured in the Lorsban treated plots throughout the test, although they were less abundant than in the non-treated plots. Within a given crop, from 60 to 70% of the parasitoids captured were from the plots without insecticide. *E. nigricephala* was the most commonly collected parasitoid of *B. argentifolii* in cucumber, cantaloupe, and collard. In tomato, *E. nigricephala* and *Eretmocerus sp.* were the most commonly collected parasitoids.

Investigator's Name(s): Gregory S. Simmons, Kim Hoelmer, Robert Staten, Theodore Boratynski.

Affiliations & Locations: USDA, APHIS, PPQ, Western Region & Phoenix Plant Methods Center, Brawley, CA and Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: February 1994 - December 1994.

Biological Control of Bemisia in Spring Melons

The primary goal of this project was to increase biological control of *Bemisia* in spring melons by rearing and releasing several species of *Bemisia* parasites. Native parasites of *Bemisia* (*Eretmocerus* sp & *Encarsia* spp.) are not effective against *Bemisia* on spring melons and levels of parasitism are generally low on these crops in the Imperial Valley of California. It is in the spring melon crop where *Bemisia* populations first start to rapidly increase. If a more effective parasite against *Bemisia* infesting spring melons was introduced in these agroecosystems, it should result in lower whitefly populations on successive summer crops and lead to higher populations of parasites at the beginning of the next planting cycle.

Shipments totaling 102,225 adults of *Eretmocerus* nr. *californicus* ex Brawley, CA(M94001) and 113,200 adults of *E.* nr. *mundus* sp. A ex Padappai, India (M92019) were received from USDA, APHIS, PPQ, Biological Control Laboratory in Mission, TX and introduced into our greenhouse insectary beginning in February. From this parent stock we produced 1.1 million *E.* nr. *californicus* and 1.3 million *E.* nr. *mundus* sp. A, an increase factor of 11x. Of these parasites, 334,000 pupae of *E.* nr. *californicus* and 536,000 pupae of *E.* nr. *mundus* sp. A were released into 18 one half acre plots of melons for a total of nine replicate release sites for each species. The remainder of these parasites were used in seasonal inoculations in Arizona cotton. In addition to the parasites produced from the rearing, 1.7 million *E.* nr. *californicus* ex Phoenix, AZ obtained from a commercial source were also released. *E.* nr. *mundus* sp. A comes from an area where growers traditionally rely on natural enemies to control whitefly. *E.* nr. *californicus* was selected to directly compare the performance of a native species against an exotic.

Preliminary results indicate that higher levels of parasitism were achieved in the release plots of both species than in non-release control plots. The highest average level of parasitism was 35% in the *E.* nr. *mundus* sp. A release plots versus 26% for *E.* nr. *californicus* release plots and 11 % for the control plots. For most sample dates, there was significantly higher levels of parasitism in release plots than control plots. There was some parasitism in control plots due to parasitism caused by native species of *Eretmocerus* and possibly due to movement of parasites out of nearby release plots.

There was an increase in the number of whitefly pupae per square centimeter of leaf for all plots. The highest level of whitefly occurred on 19 June with an average value of 3 whitefly pupae per square centimeter of leaf in control plots versus 2.2 whitefly pupae per square centimeter for release plots of both species. On most sample dates, there were lower number of whitefly in release plots than in control plots though these differences were not significant. Wasps collected from emergence samples from release plots have been tentatively identified as *E.* nr. *mundus* species A, indicating that field development of this exotic species has occured.

These results suggest that *E.* nr. *mundus* sp. A is a more effective parasite than the native species *E.* nr. *californicus* in melon crops. There were higher levels of parasitism in the *E.* nr. *mundus* sp. A release plots despite releasing about 3.8x more parasites in *E.* nr. *californicus* release plots. Thus we believe we have achieved one of our goals in discovering an exotic species more effective in melons than the native species.

A similar project is currently underway in fall cole crops and evaluation will continue into January. Three species of *Eretmocerus* from the Mission Biological Control Laboratory are being evaluated: *Eretmocerus* nr. *mundus* sp. A ex Padappai, India (M92019); *Eretmocerus* sp. ex Mission, TX (M94003); and *Eretmocerus* sp. ex College Station, TX (M94002). Results at this date are preliminary and will be reported at a later date.

Investigator's Name(s): Michael T. Smith.

Affiliations & Locations: USDA, ARS, MSA, Southern Insect Management Laboratory, Stoneville, MS.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: June 1993 - June 1994.

Evaluation of Exotic Parasitoid Species from Areas of *Bemisia tabaci* Origin

This research program is focused on the evaluation of exotic parasitoid species from areas of *Bemisia tabaci* origin for use in control of *Bemisia argentifolii* in very select geographic areas and on high value cash crops in the United States (Imperial Valley in California, Rio Grande Valley in Texas, and Florida), and identification of key parasitoid efficacy parameters.

Research was conducted on the evaluation of *Encarsia formosa* against the silverleaf whitefly, *B. argentifolii*. Two geographically distinct populations of *E. formosa* were evaluated, one from Greece and a second from Egypt. Investigations of both biological parameters (i.e. age specific fecundity, developmental rate, net reproductive rate, intrinsic rate of increase, etc.) and behavioral performance (i.e. percent time spent in various behaviors, etc.) were conducted under a range of different temperature regimes which included temperatures found in the two geographic areas of origin.

Results from these studies showed that temperature strongly influences parasitoid efficacy, with the Greece strain performing optimally at 16°C and the Egypt strain performing optimally at 26°C. The temperature conditions from which these exotic parasitoids originated correlate closely with the temperature in which their performance was optimal. Therefore, these results suggest the existence of a climatic-species adaptation in *E. formosa*, which leads to the tentative conclusion that these 'ecotypes' are adapted to precise ecological conditions.

Investigator's Name(s): Don C. Vacek and Raul A. Ruiz

Affiliations & Locations: USDA, APHIS, PPQ, Mission Biological Control Laboratory, Mission, TX.

Research & Implementation Area: Section D: Biological Control; and Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1993 and 1994.

RAPD-PCR Identification of Natural Enemies of SPWF

The integration of molecular genetic techniques into quarantine importation and culture of exotic natural enemies has enhanced the implementation of biological control of *Bemisia tabaci*, biotype B (SPWF). The Mission Biological Control Laboratory (MBCL) serves as the primary quarantine for USDA in the importation of natural enemies of SPWF. Voucher specimens of the natural enemies imported and cultured in the quarantine laboratory are provided to both systematists and the MBCL Genetics Diagnostics Laboratory. While systematic determinations are in progress, specimens are rapidly and reliably identified with genetic fingerprints produced by the technique of RAPD-PCR (randomly amplified polymorphic DNA-polymerase chain reaction). The *Encarsia* populations will most likely be classified as the following species: *E. formosa*, *E. transvena*, *E.* nr. *strenua*, *E. pergandiella*, and *E.* nr. *pergandiella*. A total of 34 *Encarsia* populations from 12 countries (Africa, Cyprus, Egypt, Greece, India, Malaysia, Nepal, Philippines, Spain, Taiwan, Thailand, and U.S.A.) were divided into 13 RAPD pattern groups which generally followed species designations, where available. The *Encarsia* patterns were distributed as follows: three unique to the U.S.A., four unique to Southeast Asia, four not found in U.S.A. and Southeast Asia, one not found in the U.S.A., and one widely distributed. A total of 15 *Eretmocerus* populations (representing *Eretmocerus spp.* and several undescribed species) from 6 countries (Egypt, India, Spain, Taiwan, Thailand, and U.S.A.) were divided into 9 RAPD pattern groups. The *Eretmocerus* patterns were distributed as follows: four unique to the U.S.A., three unique to Southeast Asia, and two not found in U.S.A. and Southeast Asia. Genetic fingerprinting with RAPD complements systematic determinations and is an effective way to identify insects for delivery of a biological control program.

Investigator's Name(s): S. Wraight[1], R. Carruthers[2], S. Jaronski[1], C. Bradley[1], S. Galaini-Wraight[1], N. Underwood[1], P. Wood[1], J. Garza[2], and J. Britton[1].

Affiliations & Locations: Mycotech Corp., Butte, MT 59702[1]; and USDA, ARS, Subtropical Agricultural Research Laboratory (SARL), Weslaco, TX 48596[2].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: April 1994 - November 1994.

Efficacy of Fungal Pathogens Against Silverleaf Whitefly on Field Crops in South Texas

Mycotech Corp. and USDA-ARS are working cooperatively to develop several strains of entomopathogenic fungi for biological control of *Bemisia* spp. Four isolates of *Beauveria bassiana* and one of *Paecilomyces fumosoroseus* were evaluated in small-scale field trials at SARL during 1994. Fungal spores were applied in aqueous suspension at spray volumes of 25 to 50 gallons per acre. Each treatments was applied in four replicate plots; plots measured four rows (40-80 inch spacing) x 25-30 feet in length.

Consistently high levels of whitefly control were achieved in experimental plots of cantaloupe and cucumber during both the spring and fall seasons. Fungal treatments of 2 E 13 conidia per acre applied by backpack air-assist sprayer at 4-5 day intervals reduced nymphal populations 25-40% within 7 days and 75-95% within 21 days of initial applications. Applications of the same dose at 7 and 10 day intervals produced similar results. A reduced dose of 5 E 12 spores per acre was as effective as the high dose when applied at 4-5 days intervals but less effective when applied every 10 days. *B. bassiana* and *P. fumosoroseus* produced equal levels of infection under field conditions. High rates of migration of adult whiteflies into the small test plots precluded quantitative assessment of spray impacts on adult populations. During the trials, infected adults were observed on foliage in virtually all treatment plots, including untreated controls. Nearly all of these adults (>95%) were overgrown with *P. fumosoroseus*. This was the case even in *Beauveria*-treated plots.

Trials with *B. bassiana* and *P. fumosoroseus* were also conducted in cotton during the summer and in spring and fall-planted tomatoes. The high dose of 2 E 13 conidia per acre applied at 4-5 day intervals produced only low levels of infection in cotton. The spring tomato test was also unsuccessful. However, in the fall trial, high-dose treatments of tomatoes with *B. bassiana* and *P. fumosoroseus* conidia produced greater than 90% reduction of nymphal populations.

Larger scale trials are planned for 1995 which should allow assessment of treatment effects on total whitefly populations.

(Results reported in oral and poster presentations)

TABLE D. Summary of Research Progress for Section D - Biological Control, in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Yr. 3: Continue biological studies; determine effectiveness of species under various habitat and weather conditions.	X		Surveys continued in Arizona, California, Texas and South Carolina. At least one *Encarsia* sp. together with an *Eretmocerus* sp. were identified in each state. In the San Joaquin Valley of CA, the overall percentage parasitism was $\leq$ 1.5% during 1993-1994. Seven parasitoid species and five predator species were collected from the Lower Rio Grande Valley of TX during 1994; yet, this assemblage of 12 species was unable to control *Bemisia* populations below economic injury levels. A lack of similar sampling methodologies between surveys continues to hamper detection of population patterns across studies. The extreme environmental conditions associated with the desert Southwest remains a major obstacle to the increase in natural enemy abundance and diversity. Use of monoclonal antibody studies suggest that *Orius tristicolor, Lygus hesperus, Chrysoperla rufilabris* and *Georcoris punctipes* may be regionally dominant predators of whitefly eggs.
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies.	Yr. 3: Evaluate refuse plantings as field insectaries on larger scale.		X	Small-scale experimental plantings consisting of sunflower, collard, kale and kenaf continue in Texas and California. There are no known plans for evaluating field insectaries on a larger scale. In the Imperial Valley of CA, refuge plantings have had limited impact on adjacent plantings of cantaloupe and cole crops due to the poor performance of the indigenous parasitoids in these crops. It is hoped that the introductions of exotic natural enemies will overcome this problem. Additionally, other plant species are currently being evaluated in California for their potential as refuge plants. Initial findings indicate that Roselle (*Hibiscus sabdariffa* var. *sabdariffa*) provides a favorable environment for parasitoids and possesses favorable growth characteristics.
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Yr. 3: Continue collections; determine habitat "fit" for each candidate; assess interactions with native species.	X		In 1994, additional species of natural enemies were imported from Argentina, Brazil, Cyprus, Italy, Israel, Malaysia, the Philippines, Taiwan and Thailand. These collections yielded three fungal pathogens (*Paecilomyces fumosoroseus*, *Fusarium coccophilum* and *Beauvaria bassiana*), at least 6 species of *Eretmocerus* and *Encarsia*, and 1 predator (*Illeis koebele*). Studies with strains of *Encarsia formosa* from Greece and Egypt suggest the occurrence of climatic adaptation in the two strains. No studies assessing the interactions of exotic natural enemies with native species have been reported. These studies are essential to understanding the impact of hyperparasitic females (i.e., many of the *Encarsia*) and effective structuring of natural enemy communities necessary to achieving biological control.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
D.4 Determine natural enemy host selection processes and mechanisms.	Yr. 3: Determine factors affecting interactions of host foraging mechanisms, hosts and host plants.	X		Studies on peanut and soybean suggest parasitoids have either different parasitization efficiencies or different microhabitat preferences that are based on foliar pubescence of their host plant. Behavioral studies examining the tritrophic relationships involving *Bemisia* and *Delphastus pusillus* suggest that foraging efficiency is influenced by the phenotypes of both the whitefly and its host plant. Laboratory studies describing reproduction and attack behaviors of *Eretmocerus* nr. *californicus* provide background life history data against which biological control efforts could be improved.
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Yr. 3: Conduct tests on technical feasibility of inoculating/augmenting predator/parasite populations for suppression of SPW.	X		Significant efforts were devoted to field evaluations of mass-produced natural enemies. Successful biological control in field crops appears to be limited to areas where mass-movements of adult whiteflies are absent. In addition, various strains of *Encarsia formosa* failed to provide control on eggplant in Hawaii and failed to establish within field cages in the Imperial Valley, CA. However, releases of 2 species of *Eretmocerus* into cotton in the San Joaquin Valley, CA provided significant reductions of whitefly densities. Use of *Eretmocerus* nr. *californicus* may be useful in inundative biological control in poinsettias.
D.6 Determine effects of pathogens on regulating SPW populations.	Yr. 3: Evaluate for efficacy and persistence in small plots; develop formulations, evaluate for micotoxins.	X		Significant advances in this area of research were reported for 1994. Trials with a commercial strain of *Beauveria bassiana* for control of *Bemisia* infesting greenhouse tomatoes and ornamentals, and for cotton in the southern US provided control similar to the best insecticide-based programs. Separate trials with 4 isolates of *Beauveria bassiana* provided consistently high levels of whitefly control in experimental plots of cantaloupe and cucumber during both the spring and fall seasons. Trials conducted in cotton during the summer and in spring-planted tomatoes yielded poor results, yet trials in fall-planted tomatoes produced > 90% reduction in whitefly populations. Continued, large-scale testing in planned for 1995.
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Yr. 3: Challenge selected natural enemies to develop resistant strains.		X	Numerous insecticide compatibility studies were conducted in 1994. While data generated by these studies aid in the development of IPM programs, they do not represent an advancement between Years 2 and 3. No efforts are planned for developing insecticide-resistant natural enemies; at least until successful biological controls agents can be identified.
D.8 Systematics of predators, parasites and pathogens.	Yr. 3: Review critical genera; establish limits of relevant species worldwide.	X		A thorough systematic review of *Encarsia* and *Eretmocerus*, the two major genera of *Bemisia* parasitoids, continued in 1994 using molecular, behavioral, and morphometric techniques.

Research Summary
Section D: Biological Control
Compiled by: Kevin M. Heinz & Oscar P.J.M. Minkenberg

Biological control-oriented research has increased from 18% of the total abstracts in the first annual review to approximately 31% of the total abstracts submitted for this third annual review. This increase, in part, reflects several significant advances in biological control of *Bemisia* sp. While these advances are outlined in more detail in Table D, several areas of research deserve further recognition.

During 1994, several large-scale classical (or inoculative) and augmentative biological control programs were conducted in California, Arizona, and Texas; and on a greatly reduced scale in New York greenhouses. Augmentative biological control for use in crops in the desert Southwest continues to be problematic for a variety of reasons that include the harsh environmental conditions, unfavorable price structures (for commercialization of natural enemy release programs), and periodic mass-movements of white fly adults. Natural enemies released into less hospitable environments (the San Joaquin Valley of California and greenhouses) have significantly reduced whitefly populations in cotton and poinsettias. Unlike other augmentation programs, the availability of natural enemies for testing is not a limiting constraint. The production of large quantities of *Eretmocerus* sp. ex Arizona by the University of Arizona, in cooperation with CIBA Bunting Ltd., UK and the 6.5 million parasitoids produced by the USDA-APHIS Mission Biological Control Laboratory have significantly increased the supply of natural enemies available for testing in 1994. Management practices compatible with biological control and capable of reducing mass-movements of whiteflies should permit expansion of this strategy into other cropping systems.

Similarly, commercial involvement in the development of the fungal pathogens *Beauveria bassiana* and *Paecilomyces fumosoroseus* have also permitted a rapid proliferation of large-scale field testing. While the results from these trials have been variable, applications on the order of 2×10^{13} conidia per acre have reduced whitefly populations by more than 90% within 21 days of initial applications. The continued interaction between the commercial sector, and USDA, SAES, and university scientists should facilitate future assessments and implementation of pathogen treatments on whitefly populations.

While the taxonomic identities of many of the natural enemies remains a confusing issue for many biological control researchers, detailed systematic studies lead by Texas A&M University, University of Florida, University of California, and USDA scientists are currently in progress. Use of molecular, behavioral, and morphometric taxonomic tools have aided significantly in the identification of species and geographical strains within species as well as the phylogenetic relationships within the two major genera of *Bemisia* parasitoids, *Eretmocerus* and *Encarsia*.

Despite these significant advances, several areas remain problematic. These areas were addressed in a formal discussion. Below is a summary of the issues discussed and recommendations forwarded by the participants.

1. How may we increase the effort expended on field evaluations of indigenous and exotic natural enemies given the limited number of species currently under evaluations by comparison to the number of locally indigenous species and exotic species housed in USDA and state quarantine facilities?

<u>Positions Presented by the Participants:</u>

- The regional coordinating committee volunteered to search for avenues of funding that may expand the number of evaluation projects in the near future.

- Completion of generic environmental assessments will remedy many of the permitting problems and increase the opportunity for evaluation.

- Better taxonomic identification is needed before exotic strains, morphologically indistinguishable from the indigenous fauna, are evaluated in Florida.

- Cooperation on an international level will greatly increase the pool of interested researchers.

- Evaluations should be limited to specific target areas and crops where biological control is lacking. It was suggested that use of this focused approach would increase the numbers of species that may be evaluated for a given unit of effort.

- Strong resistance to a moratorium on foreign exploration was voiced. Many ecosystems have yet to be searched for potential biological control candidates.

- Evaluations of predators lag far behind evaluations of parasitoids. Parasitoid researchers tend to sample inappropriately for predators and predator researchers tend to sample inappropriately for parasitoids. Better sampling methods need to be used if the impacts of the indigenous and newly released natural enemies on whitefly populations are do be correctly evaluated.

2. When attempting to manipulate a habitat for the conservation of natural enemies, how are plants selected for use in a refuge?

Positions Presented by the Participants:

- Originally by trial-and-error. However, an effort is in progress to evaluate plants native to the region where the refuge is to be established.

- When attempting to conserve the natural enemy fauna, whether the natural enemies of interest can survive and reproduce on *Bemisia* must be considered. *Bemisia* lacks the complete array of nutrients necessary to support most predator species examined.

3. Can we attribute the rapid expansion in the area of pathogen research to their potential price structure (as compared to the existing price structure for parasitoids and predators)?

Positions Presented by the Participants:

- Price is only one part of the story. From the beginning, industry acknowledged that fungal pathogens would have to be competitive with insecticides and planned accordingly. In addition, growers may use existing technologies in applying fungal pathogens and this familiarity with existing technologies has led to widespread acceptance by growers to evaluate fungal pathogens on whiteflies infesting their crops.

- The rapid expansion or success of pathogen research is only in comparison to parasitoid and predator programs. The question is, what is wrong with parasitoid and predator programs? Too much hope is placed on classical biological control and more emphasis needs to be placed on augmentation technology. Mass-rearing approaches need to be modified to lower augmentation costs. Maybe the success of pathogen research should be used as a model for parasitoid and predator research programs.

- Education at the grower level is the key. Growers must be shown how to make better use of natural biological control. Growers must be taught to look at their crops differently than they do now.

4. Summary

Progress over the previous three years has been slow in two areas, the enhancement of habitats to conserve natural enemies (D2), and compatibility of pesticides with *Bemisia* natural enemies (D7). Other areas have experienced significant progress; as an example, the effects of pathogens on populations of *Bemisia* (D6). One area, the evaluation of parasites and predators after their release into the environment (D1 and D5) continues to suffer from insufficient funding. With only two years remaining on the project, only a few research groups in the US have the financial resources necessary to properly evaluate natural enemies released into agricultural systems. Failure to increase the number of research projects in this area will ultimately mean that many of the species currently in quarantine, and certainly almost all of the species yet to enter quarantine, will be released without any scientific evaluation.

Reports of Research Progress
Section E. Crop Management Systems and Host Plant Resistance
Co-Chairs: Eric Natwick and Alvin Simmons

Investigator's Name(s): M.J. Berlinger, Sarah Lebiush-Mordechi.

Affiliations & Locations: Entomology Laboratory, ARO, Gilat Reg. Experiment Station, M.P. Negev, 85-280, Israel.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1991-1994.

Physical Means for the Control of *Bemisia tabaci*

A variety of physical means are known to suppress insect pest populations. They function strictly mechanically, or include behavior-based effects. When colors are used, the insect's behavior (attraction or rejection of the color) is strongly involved. Colored mulches fall into this category. With mechanical barriers or electromagnetic methods, insect behavior is not involved. Mechanical barriers include fine-meshed screens, spun-bonded sheets, sticky materials and over-pressure induced air currents. They are aimed mainly at preventing migratory insects from reaching the plants, rather than controlling insects which are already present in the crop. The screen mesh which prevents passage of whiteflies mechanically, must of course be smaller than the insect's body size. They will also efficiently prevent the influx of bigger insects like aphids, leafminer flies, etc., but at the same time they may hamper ventilation and cause the greenhouse to overheat. Attempts to use less dense screens and to compensate by repellent colors has not proven to be very effective in the case of whiteflies.

Greenhouse ventilation systems strongly affect the influx of insects. Forced ventilation based on sucking air out of the greenhouse caused underpressure indoors and increases significantly the influx of insects compared with passive ventilation. Positive air pressure, induced by actively pushing air through an insect-proof filter into the greenhouse, reduced whitefly influx by about a third, compared with a naturally (passively) ventilated greenhouse. This active method, although energy consuming, solves two problems simultaneously: it reduces whitefly influx and ventilates the greenhouse.

Outdoor crop protection by unwoven spun-bonded polypropylene or polyester sheets spread over the plants, is very efficient as long as it does not cause overheating or interference with crop pollination. The efficacy of ground mulching with colored plastic sheets decreases virus infection rates at the first period of the crop growth. Whitewash sprays on plants reduced whitefly attack and virus transmission. Sticky polybutenes sprayed onto the plants, once their phytotoxicity is overcome, prevent any whitefly feeding and virus transmission.

In summary: the enhanced development and use of pesticides, following world war II, has caused controversy. It has brought, though temporarily, a release from severe insect damage and contributed to the "green revolution". But, it also retarded the research and development of alternative methods. It seems that we must "catch-up" these lost 50 years and put much more effort into the search for and exploitation of environmentally safe control means.

Investigator's Name(s): L.D. Godfrey and P.F. Wynholds.

Affiliations & Locations: Department of Entomology, University of California, Davis, CA.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1 April 1994 - 31 December 1994.

Susceptibility of San Joaquin Valley Acala Cotton Varieties to Silverleaf Whitefly

Susceptibility of the approved San Joaquin Valley acala cotton varieties to silverleaf whitefly was compared in field plots at the U.C. Cotton Research Station at Shafter, CA. Studies were conducted in 1993 and 1994. Varieties evaluated in 1993 were GC-510, GC-610, GC-702, SJ-2, Prema, Maxxa, Royale, DP 6166, DP 6100, CB-7, CB-305, and CBX-392. In 1994, Kings Acala Plus and GC-717 were added to the study, whereas GC-610, CB-315, CB-7 and CB-305 were not evaluated.

Silverleaf whitefly populations were low in the plot area in 1993 and 1994. In 1993, populations ranged from 11 to 27 nymphs per 20 leaves (totaled over 4 dates) with no significant differences among varieties. In 1994, SWF infestations were first noted on 22 July. There were no trends in adult SWF densities per leaf among the varieties. Whitefly populations, nymphs + empty pupal cases, ranged from 8.8 to 41.2 per 20 leaf sample (totaled over 4 dates). Again, there were no significant differences among the varieties. Populations tended to be lowest on DP 6100, which is a "smooth leaf" cotton. SWF populations were also low on DP 6166. Trichome counts were made and averaged 0.5 trichomes per sq. cm. on DP 6100 and ranged from 32 to 60 trichomes per sq. cm. on the other varieties tested in 1994.

Investigator's Name(s): H. J. McAuslane, F. A. Johnson, B. R. Sojack & D. L. Colvin.

Affiliations & Locations: University of Florida, IFAS, Gainesville, FL 32611-0620.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: July - November, 1994.

Resistance to Silverleaf Whitefly in Soybean Isolines Varying for Foliar Pubescence

In 1993, we assessed field infestations of silverleaf whitefly on 3 near-isolines of soybean (glabrous – D90-9216, pubescent – D75-10169, and hirsute – D90-9220 [obtained from E. Hartwig, USDA-ARS, Stoneville, MS]) and on 'Sunrunner' peanut. We were investigating the use of soybean as a trap crop to reduce infestation of whiteflies in peanut. In 1994, we repeated the field evaluation and conducted greenhouse choice experiments to determine the mechanism of resistance observed in 1993 in glabrous soybean.

Field experiment - The field was planted 10 June, 1994. Each plot consisted of 8 6-m rows of either glabrous, hirsute or pubescent soybean or peanut, flanked on each side by 8 rows of peanut. Treatments were replicated 4 times in a randomized complete block design. Sampling was conducted at 10-day intervals from 4 August until 4 October. Twenty leaflets were sampled from each treatment (from the fourth fully expanded leaf below the terminal leaf on peanut and from the fifth fully expanded leaf on soybean). Whitefly eggs, young instars, fourth instars and red-eyed nymphs were counted on 3.34-cm^2 discs taken from each leaflet.

Peanut leaflets were hairless. Glabrous soybean had short hair 'stubs'. Pubescent soybean averaged 2.94 ± 0.17 hairs/mm^2 (mean ± SEM), with an average length of 1.41 ± 0.04 mm, and hirsute soybean averaged 17.42 ± 1.35 hairs/mm^2, with an average length of 1.05 ± 0.04 mm.

As in 1993, peanut supported the lowest populations of whitefly. Pubescent and hirsute soybean supported the greatest numbers of whiteflies, significantly greater than glabrous soybean until 4 September. After this time, pubescent and hirsute soybeans began to senesce rapidly while glabrous soybean continued to produce new vegetation and support greater numbers of whiteflies.

Greenhouse choice experiment - Soybeans were planted in 13-cm-diameter pots and were inoculated with *Rhizobium.* At the V4 stage, one plant of each genotype (glabrous, pubescent and hirsute) was placed randomly in a 60 x 60 x 60 cm screen cage in a greenhouse. Six cages were set up at a time and the experiment was conducted 4 times for a total of 24 replicates. 150 mating pairs of whiteflies were released into the center of each cage. For 3 days after introduction, we counted numbers of adults resting on the underside of each leaf of each genotype. On the third day, leaves were removed from the plants, their areas measured and the number of eggs on each leaf counted under 12x magnification. All data was standardized on the basis of leaf area.

The number of adults resting on each genotype did not differ significantly over the 3 days of observation. However, significantly more eggs were laid on pubescent (246 ± 19 per leaf, mean ± SEM) and hirsute soybean (215 ± 18) than on glabrous soybean (165 ± 16). Based on the leaf area available for oviposition, eggs were laid on pubescent soybean 39% of the time, on hirsute soybean 34% of the time, and on glabrous soybean 27% of the time. The partial resistance observed in glabrous soybean appears to be due, in part at least, to antixenosis.

Investigator's Name(s): James D. McCreight.

Affiliations & Locations: USDA, ARS, U.S. Agricultural Research Station, Salinas, California.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January 1994 - January 1995.

Repeatable Protocol for Evaluation of Lettuce for Reaction to Silverleaf Whitefly Feeding

Lettuce is adversely affected by silverleaf whitefly feeding in the lower desert areas of Arizona and California. Reaction of varieties, breeding lines and plant introductions to whitefly infestation and feeding has not been reported. In crops such as lettuce (Lactuca sativa L.) where vegetative parts (leaves, stems, petioles) rather than fruit or seeds are the marketable commodity, it is critical that the entire plant be free of whiteflies and blemishes, i.e. yellowing, necrotic spots. In order to accomplish this, the entire plant should be protected throughout the growing season or perhaps a during a shorter, critical period prior to harvest. Oftentimes, there are few blemishes to affect plant appearance while vegetative growth is reduced. This requires a longer growing period to reach a desired size for trade, or it results in a smaller than desired product which usually commands less per unit in the market place.

The objective of this research was to establish a repeatable protocol for evaluation of lettuce for reaction to silverleaf whitefly feeding. Evaluation of lettuce in field conditions is hampered by lack of an adequate control for comparison. Efforts were directed, therefore, towards a greenhouse procedure using non-destructive measures of plant response to silverleaf whitefly infestation. A testing procedure was established whereby plants are infested daily.

Effects on plant growth have been evident as early as seven days after initial infestation with silverleaf whitefly adults. Differences between infested and control plants are similar to those observed in naturally-infested field plantings: chlorosis, senescence, stunting, shorter leaf length, narrower leaf width, smaller leaf area, and reduced fresh weight. Results to date suggest it may be necessary to control the number of silverleaf whiteflies per plant in order to not overwhelm moderate levels of resistance. Further work must be done to develop a precise and accurate means of assessing response of lettuce to silverleaf whitefly.

Investigator's Name(s): S. E. Naranjo, H. M. Flint, and T. J. Henneberry.

Affiliations & Locations: Western Cotton Research Lab, USDA-ARS, 4135 E. Broadway Rd., Phoenix, AZ 85040.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: April 1 - November 1, 1994.

Integration of Irrigation Strategies and Action Thresholds for Management of *Bemisia tabaci* in Cotton

Over the past several years we have been studying the effect of cotton plant water stress on the sweetpotato whitefly in Arizona. Using weekly and biweekly furrow irrigation we have demonstrated that whitefly populations are significantly lower in cotton plots that are under lower levels of water stress (measured by leaf water potential). These effects have been shown for both upland and Pima cottons. Further, lint yields were significantly higher and lint sugar content was significantly lower in weekly-irrigated cotton. In part these yield effects were due to slightly greater amounts of water applied over the season in weekly irrigated plots. We hypothesized that reduction in plant water stress through more frequent irrigation would reduce whitefly populations and thus reduce the number of insecticide applications needed to suppress populations for acceptable yields and lint quality. In 1994 we tested this hypothesis in large (0.1 ha) replicated plots of Deltapine 50 at the Maricopa Agricultural Center. Half of the 48 plots received irrigation on a weekly basis and half on a biweekly basis. Within each irrigation regime we used either fenpropathin + acephate or buprofezin for whitefly control and these materials were applied by ground rig at one of three action thresholds based on adult counts from the fifth mainstem node leaf (1, 5 or 10 adults/leaf). This resulted in a total of 12 treatments replicated 4 times each. Egg and nymph densities (3.88 cm^2 disks from the fifth mainstem node leaf) and adult densities were estimated weekly in all plots from 31 May through 30 August. Plots were defoliated on 1 September and machine harvested on 20 September.

As in previous years, whitefly populations were significantly lower on a seasonal basis in weekly in comparison with biweekly-irrigated cotton plots (37% fewer eggs; 31% fewer nymphs; 22% fewer adults). As expected, the combination of fenpropathin + acephate was significantly more effective on a seasonal basis than buprofezin at suppressing all stages of the whitefly (76% fewer eggs; 65% fewer nymphs; 48% fewer adults). Using action thresholds of 1, 5 or 10 adults per leaf, biweekly plots required 5, 3 or 2 treatments, respectively, but weekly plots required only 4, 2 or 2 treatments, respectively. Thus, weekly irrigation permitted one less spray at the low and medium action thresholds. On a seasonal basis egg and nymph densities did not differ between either low and medium action thresholds nor medium and high thresholds, but there was a significant difference between low and high thresholds. The density of adults and lint yields did not differ between medium and high thresholds, but both were significantly different from the low threshold. Surprisingly, yields were 8.2% higher in biweekly-irrigated plots in comparison with weekly-irrigated plots. This was opposite of results from 1992 and 1993 at the same site. An intense hail storm in mid-August knocked much of the seed cotton from open bolls and may have influenced our estimation of yields (machine pick + hand picked from 6 row-meter of ground). Preliminary lint quality analysis indicated that stickiness was similar for all treatments and low enough not to be a significant problem in processing. Further analysis with the thermo-detector are underway. In general, results suggest that water management may reduce whitefly populations and the number of insecticide applications, however additional economic analyses are needed to evaluate the overall usefulness of this approach.

Investigator's Name(s): Thomas M. Perring[1], Keith S. Mayberry[2], and Eric T. Natwick[2].

Affiliations & Locations: Department of Entomology, University of California, Riverside, CA[1]; UC Cooperative Extension, University of California Desert Research and Extension Center, Holtville, CA[2].

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1993.

Silverleaf Whitefly Management in Cauliflower Using a Trap Crop

The study was conducted to determine if planting cauliflower with a melon trap crop would reduce the number of whitefly adults ovipositing on the cauliflower, resulting in a subsequent decline in the number of immatures on the cauliflower.

Four commercial cauliflower fields were chosen for the study. Within each field, 8 plots were established. Four of the plots were transplanted with a row of cantaloupes sown adjacent to the cauliflower and 4 plots were transplanted without the melons. Each sampling period, 15 cauliflower plants were selected randomly in each plot and 3 leaves (upper, mid, and lower) were removed from each plant. On each of these 3 leaves 4, 1 square cm areas were sampled. All eggs, crawlers, nymphs and red-eyed nymphs were counted. For analyses, all nymphal instars were combined.

Analysis consisted of standard analyses of variance with a probability level of 0.05 used to determine statistical differences.

Unexpectedly low whitefly numbers were sampled on all plots due to the application of Admire® 240 FS by the growers. However, even with the low numbers, the data indicate that trap cropping with melons can reduce whitefly pressure on cauliflower. While the data are less than spectacular, they do indicate some benefit to intercropping cauliflower with melons. In the absence of Admire, this benefit may be more robust.

Investigator's Name(s): David G. Riley.

Affiliations & Locations: Texas Agricultural Experiment Station, 2415 E. Hwy 83, Weslaco, Texas 78596.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January 1994 – December 1994.

Evaluation of Sweetpotato Whitefly on Selected Melon Cultivars

The b–strain sweetpotato whitefly, *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) or the new species name of silverleaf whitefly, *Bemisia argentifolii* (SW), was evaluated on selected melon cultivars in treated and untreated field plots in 1992, 1993 and 1994 at Weslaco, Texas. Whitefly ovipositional preference and plant tolerance were evaluated by monitoring whitefly numbers and plant yield response. Plant characteristics, damage and yield were evaluated and correlated with whitefly numbers.

The plant introductions (PI) in this test (PI116915, PI125966, PI126125, PI125951) were hairy–leaf types as evidenced by the number of long trichomes per leaf area. Positive correlations occurred between long–leaf trichomes and numbers of whitefly adults and immatures. Also there was a negative correlation between long–leaf trichomes and yield suggesting that the presence of long trichomes is not a desirable trait, however this may have been an artifact of the low–yielding hairy–leaf PI's being compared to smoother–leaf commercial cultivars. Yield differences were dramatic between the commercial cultivars and PI's, but also between certain commercial cultivars. Tam Sun, HMX 9583, Hymark, Mission, Cruiser produced the greatest value of melons followed by Primo, Mainpak and Explorer. In the 1994 test, the untreated plots experienced high numbers of whiteflies resulting in yield reductions in all cultivars. This demonstrated the overall susceptibility of this crop to whitefly damage and suggested that measureable tolerance to whiteflies in melons will probably only be seen at low to moderate whitefly population density with the more commonly available plant material. Differences between cultivars in oviposition rates and nymphal numbers were detected in the spring 1994 field trial. In other tests conducted in the greenhouse, life–table data for whiteflies indicated a ca. 16% difference in whitefly adult survivorship between two cultivars, HMX 9583 and Tam Sun. Further life-table tests are underway.

Investigator's Name(s): John C. Snyder and Alvin M. Simmons.

Affiliations & Locations: Department of Horticulture and Landscape Architecture, University of Kentucky, Lexington, KY; USDA-ARS, U. S. Vegetable Laboratory, Charleston, SC.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1994.

Day Length Affects Oviposition Preference of *Bemisia* on *Lycopersicon Hirsutum*

To assess the possibility of antixenosis and role of type IV trichomes in resistance to *Bemisia argentifolii*, two clones of single plants of six accessions of *Lycopersicon hirsutum*, representing diverse chemotypes, were grown in each of three day lengths (8, 12, and 16 hours). Plants were removed from growth chambers and one leaf per plant was use in a non-choice bioassay. The plants were then randomly placed on a bench in a greenhouse heavily infested with *B. argentifolii* for a choice bioassay. Data were collected on number of adults on the second fully expanded leaf at 6, 12, and 18 hours, and on number of eggs at 24 hours after exposure. Leaf area and type IV and VI trichome densities were also determined. For the non-choice bioassay, leaflets were exposed in a 2.5 cm diameter area within a modified petri dish. The number of adults on a leaflet within each exposed area was determined at 8, 12, and 18 hours. After 24 hours, the number of eggs deposited on each exposed area was determined.

Differences in oviposition were mainly associated with day length and accession; there was no interaction between accession and day length. In both choice and non-choice tests, plants grown under the 8 hour day had the least oviposition and the highest type IV density. Plants grown under the 12 hour day length were the most susceptible, having the most oviposition. Type IV density also differed among day lengths; type IV density was greatest (24 per mm^2) under the 8 hour day length and considerably less under the 12 and 16 hour day lengths (8 and 5 per mm^2, respectively). Among accessions, LA1353, LA1927, and LA2329 were the most resistant based on both the choice and non-choice bioassays. Differences in oviposition by whiteflies among day lengths, especially when plants were grown under the 8 hour day length, indicate that type IV density played a role in oviposition preference. However, type IV density does not explain all behavioral differences by *B. argentifolii* among accessions; other factors, perhaps the composition of the trichome secretion, also may have mediated oviposition preference. In the choice bioassay, numbers of adults on the leaves were highly correlated with oviposition (r=0.80). However, in the non-choice bioassay, the numbers of adults were not correlated with oviposition (r=0.11). The role of composition of trichome secretions in host selection and oviposition preference are under investigation.

Investigator's Name(s): Jorge Sosa-Coronel.

Affiliations & Locations: INIFAP, Mexicali, B.C. México.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: October 1992 - January 1993; October 1993 - January 1994.

Response of Brocoli Cultivars to *Bemisia argentifolii* Bellows and Perring

The response of brocoli cultivars was studied as far as the silverleaf whitefly preference. Two experiments were carried out. The first in the fall-winter 1992-1993 and the second during the fall-winter 1993-1994. In the first experiment nine cultivars were included (cruiser, commander, sprinter, emperor, pirate, greenbelt, green duke, arcadia and legend). In the second experiment seven cultivars were included (arcadia, emperor, greenbelt, sprinter, marathon, shogun and ninja). In both experiments a complete randomized block design with four replications was used. Counts of pupa (fourth instar) were done in a 1 cm diameter disk (0.7854 square centimeters); six disks taken diagonally to the length of the leaf were used. The data was analyzed by comparison of the regression lines for the accumulated counts of pupa.

The analysis of variance showed significant differences among cultivars. Cultivars arcadia (42.6 and 153 pupa/plant), shogun (145.9 pupa/plant) and green duke (27.7 pupa/plant) showed the highest number of pupa per plant. Cultivars emperor (15.7 and 44.3 pupa/plant), greenbelt (12.6 and 45.7 pupa/plant), ninja (70.7 pupa/plant), pirate (8.9 pupa/plant) and marathon (59.4 pupa/plant) had the lowest number of pupa per plant. Cultivars sprinter (24.4 and 78.6 pupa/plant) and commander (20.6 pupa/plant) were intermediate.

Investigator's Name(s): Wilant A. van Giessen[1], Chris Mollema[2], and Kent D. Elsey[1].

Affiliations & Locations: USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC 29414[1]; DLO-Centre for Plant Breeding and Reproductive Research, Dept. of Vegetables and Fruit Crops, Wageningen, The Netherlands[2].

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1991 - 1993.

Development of a Simulation Model for Evaluating Plant Germplasm for Antibiotic Resistance to Whitefly

Variable results using evaluation techniques for plant resistance to whiteflies have been attributed to their dependence on antixenotic factors. The aim of the present study was to obtain an evaluation method that focuses on antibiotic rather than on antixenotic resistance factors.

A deterministic simulation model was designed, incorporating life history parameters that can be measured relatively easily on individual host plants through the use of clip-on leaf cages. Parameters calculated were oviposition rate(eggs/female/day), pre-adult survival (fraction of eggs surviving until adulthood), adult survival(fraction/day), and developmental period (time period between egg stage and adult emergence). Other parameters used in the model were adult longevity (days), maturation period (number of days between adult emergence and first oviposition), and sex ratio. Population development is simulated for 150 days after which the simulated intrinsic growth rate (r_s) is calculated. The simulation model serves as a tool to combine life history components to obtain a single criterion for resistance. This criterion is the decrease in simulated intrinsic population growth rate, r_s, relative to the r_s value determined on a susceptible (control) genotype.

Sensitivity analysis of the model revealed that changes in developmental period has the most effect on whitefly population growth, followed by sex-ratio and oviposition rate, while the model was least sensitive to (pre-adult) survival. A high correlation was found between results of the sensitivity analysis of our model with those obtained for a whitefly simulation model developed in the Netherlands in 1989, which has been validated for the greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) on tomato.

This simulation model-based evaluation method was tested using the greenhouse whitefly, *T. vaporariorum* (on tomato) and the sweetpotato whitefly, *Bemisia tabaci* Gennadius (on tomato, eggplant, collards, and pepper). The evaluation method was repeated 6 times on three tomato cultivars during the course of a year in a greenhouse. The simulated intrinsic population growth rate, i.e., the criterion for relative resistance, was more consistent than the other life history parameters. Among 8 *Lycopersicon hirsutum* and 1 *L. hirsutum glabratum* accessions evaluated, three exhibited high levels of antibiotic resistance to *T. vaporariorum*. A significant correlation was found between r_s and sex-ration; the sex-ratio of whiteflies emerging on more resistant plants tended to be male-biased. Strong antibiotic resistance to *B. tabaci* was observed in pepper (*Capsisum annuum* L., cv Keystone).

This evaluation method facilitates quantifying levels of whitefly resistance and will improve efficiency in breeding programs because of its standardized character.

Investigator's Name(s): Wee Yee[1], Nick Toscano[1] and John Palumbo[2].

Affiliations & Locations: [1]University of California, Department of Entomology, Riverside, CA; and [2]University of Arizona, Department of Entomology, Tucson, AZ.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1993 - 1994.

Silverleaf Whitefly Tritrophic Interaction in Stable Ecosystem

During 1993 & 1994, alfalfa fields in Imperial County, California, and Yuma County Arizona, were sampled for silverleaf whitefly (SLW) adults, nymphs, egg and natural enemies of the whitefly. SLW were collected from five fields in Imperial and five fields in Yuma. SLW adults were collected from five sites per field using a modified vacuum (Hand-Vac). Nymphs were taken by pulling three alfalfa trifoliates per plant from each of the five sites (27-45 trifoliates were collected from each site). The trifoliates were stored in 70% EtOH, transported to the laboratory and counted. Counts consisted of SLW eggs, small nymphs (first and second instars), large nymphs (third and fourth instars) and empty exuvia. The total number of eggs and nymphs, pupae and empty pupal cases on the underside of each trifoliate was counted. Leaf areas of individual trifoliates were measured with a leaf area meter (Li Corr 3100A) to determine SLW density.

Beginning June through October, approximately 100 SLW pupae were collected per field. The pupae were transported to the laboratory and held and observed for SLW parasite emergence.

Alfalfa fields were sampled every two weeks from January 1993 up to the present. Peak abundance of 73 SLW nymphs/trifoliate in CA was reached in late September/October, and declined to less than 1 nymph/trifoliate by December. Egg and adult abundance trends reflected a similar pattern. In Yuma, AZ and in 1993, lower densities of SLW were collected than in Imperial Valley.

A greenhouse study has shown that alfalfa is a suitable development host and can support high numbers of SLW. This indicates alfalfa may contribute to SLW problems seen on other crops in the spring.

Very few natural enemies were collected during this 1993-1994 survey. No SLW pupae were found to parasitized in the Imperial or Yuma alfalfa fields surveyed.

Investigator's Name(s): R. K. Yokomi[1] and L. S. Osborne[2].

Affiliations & Locations: USDA-ARS, U.S. Horticultural Res. Lab., Orlando, FL[1]; University of Florida, Central Florida Research and Education Center-Apopka, Apopka, FL[2].

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: July through November 1994.

Mediation of Whitefly Feeding Behavior

Plant biochemical regulators (PBRs) are known to have a variety of effects on the growth and development of plants including mediation of homopteran feeding behavior. Research has begun to determine if certain PBRs, acyl sugars, insecticides (e.g., imidacloprid), and repellents can alter feeding of the silverleaf whitefly enough to impact virus transmission and induction of plant disorders such as tomato irregular ripening (TIR). Tomato seeds were soak-treated with FVCL-2 (a PBR from the USDA-ARS, Fruit and Vegetable Chemistry Laboratory, Pasadena, CA) and imidacloprid in Silwet. After air drying, the seeds were planted in potting mix, germinated, and plants grown in the greenhouse. Both FVCL-2 and imidacloprid reduced numbers of nymphs of the silverleaf whitefly on treated plants. Feeding behavior of the whitefly and the potato aphid, Macrosiphum euphorbiae (Thomas), was monitored with an AC Insect Feeding Monitor (Columbia, MO). No appreciable changes were seen in whitefly or aphid feeding behavior with the FVCL-2 treatment. Imidacloprid, however, caused more frequent probing, stylet withdrawal, and shorter duration of ingestion. This influence has not yet been evaluated for virus transmission or induction of TIR.

TABLE E. Summary of Research Progress for Section E - Crop Management Systems and Host Plant Resistance, in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
E.1 Determine effect of traditional crop production inputs on SPW population development.	Yr. 3: Develop mechanisms involved in crop production factors which greatly affect SPW biology, behavior, etc.	X		Research continued on effect of water stress on whitefly populations in cotton. Weekly irrigated plants received fewer number of whitefly adults and immatures as compared with bi-weekly irrigated plants. Weekly irrigated plants also required fewer insecticide application to maintain adults below treatment thresholds. Also, biochemical regulators were used to mediate interactions between SLWF attack on several different host plants.
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Yr. 3: Determine interactions of cultivate host sequences and weeds on SPW population development and movement.	X		Research was continued in identifying differences within and between cultivated crops to attack by SLWF, including differences within species of vegetables and cotton.
E.3 Determine effect of colored mulches, trap crops, inter-cropping, row covers, and other innovative cultural practices as potential SPW control methods.	Yr. 3: Conduct studies to determine potential of cultural practices to SPW affect SPW population development in the field and affect yield.	X		Melon used as a trap crop was effective in reducing the infestation by SLWF in cauliflower; interplanting with melon in this system seems to be beneficial. Soybean was also investigated as a trap crop in peanuts. Fine-mesh screens were evaluated for mechanical exclusion of migrating whitefly adults from greenhouse production of vegetables and ornamental crops. Forced positive air flow through whitefly-proof filters reduced the influx of whitefly and incidence of virus transmission in vegetable crops. Reflective mulches were used as whitefly repellency in squash.
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Yr. 3: Use improved evaluation techniques to identify resistance mechanisms.	X		Methods to assess host plant resistance were developed in: alfalfa, broccoli, collard, eggplant, lettuce, melon, pepper, soybean, and tomato. Resistance varied with foliar pubescence. More SLWF oviposition occurred on pubescent and hirsute near-isoline soybeans versus a glabrous genotype. In melon, there was a positive correlation between long-leaf trichomes and number of whitefly adults and immatures. Type IV and VI trichomes of *Lycopersicon hirsutum* accessions were evaluated for their role in resistance against *Bemisia*. Differences were mainly associated with day length and accessions. Plants under 8 hour day length had the most dense type IV trichomes and received the least oviposition versus 12 and 16 hour day plants. Trichome density did not explain all behavioral differences by SLWF among accessions. A simulation model for evaluating plant germplasm was developed based on antibiotic factors. A testing procedure was established to provide a repeatable protocol for evaluation of lettuce germplasm for SLWF feeding. Also, procedures were established for evaluation of SLWF feeding, honeydew contamination and sooty mold contamination in alfalfa.

Research Approaches	Goals Statement	Progress Achieved Yes	No	Significance
E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Yr. 3: Quantify effects of resistance characters on SPW, virus, and associated plant disorders.	X		High levels of resistance to SLWF were not found in any crop species or cultivars tested. Evaluation of 15 Cotton cultivars for resistance to SLWF resulted in no significant differences among cultivars in 1993 and 1994. Differences were detected among 12 melon cultivars in ovipositional rate, nymphal numbers, adult survivorship in field trials, and greenhouse lifetable studies. Significant differences were detected among 12 broccoli cultivars for SLWF colonization preference
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Yr. 3: Begin to transfer resistance factors into improved plant types.	X		Breeding lines were investigated for alfalfa. Half-sib "families" of alfalfa from a genetically diverse germplasm pool were evaluated for SLWF colonization and damage. Several crosses produced lines that had fewer whitefly immatures and less stickiness from honeydew. Selections are continuing along lines of positive response.

Research Summary

Section E: Crop Management Systems and Host Plant Resistance

Compiled by: Eric T. Natwick and Alvin M. Simmons

E.1 Determine effect of traditional crop production inputs on SLWF population development.

Research was continued on the effect of water stress on whitefly populations in cotton. Weekly irrigated plants received fewer numbers of whitefly eggs, nymphs, and adults as compared with bi-weekly irrigated plants. In addition, weekly irrigated plants required fewer insecticide applications to maintain adult populations below treatment thresholds as compared with water stressed plants. Biochemical regulators were also used to mediate interactions between SLWF attack on several different host plants.

E.2 Determine temporal and spatial effects of host plants on SLWF populations and dispersion.

Research was continued in identifying differences within and between cultivated crops to attack by SLWF, including, cultivar differences within species of vegetables and cotton.

E.3 Determine effects of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SLWF control methods.

Melon used as trap crops was effective in reducing the infestation by SLWF in cauliflower; interplanting with melon in this system seems to be beneficial. Soybean was investigated as a trap crop in peanuts. Fine-mesh screens were evaluated for mechanical exclusion of migrating, whitefly adults from greenhouse production of vegetables and ornamental crops. Forced positive air flow through whitefly-proof filters reduced the influx of whitefly by about a third and reduced the incidence of virus while simultaneously provided ventilation for the greenhouse. Row covers were found to be effective in limiting whitefly infestations and virus transmission in vegetable crops. Reflective mulches were used as whitefly repellency in squash.

E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.

Several methods were developed in various crops (alfalfa, broccoli,, collard, eggplant, lettuce, melon, pepper, soybean, and tomato) to assess host plant resistance to *Bemisia*. Cotton, melon, soybean, and tomato resistance varied with foliar pubescence. More SLWF oviposition occurred on pubescent and hirsute near-isoline soybeans versus a glabrous genotype. In melon, there was a positive correlation between long-leaf trichomes and numbers of whitefly adults and immatures. Type IV and VI trichomes of *Lycopersicon hirsutum* accessions were evaluated for their role in resistance against *Bemisia*. Differences were mainly associated with day length and accessions; there was no interaction between these two parameters. Plants gown under 8 hour day length had the most dense type IV trichomes and received the least oviposition versus 12 and 16 hour day plants. Trichomes density does not explain all behavioral differences dy SLWF among accessions. A simulation model for evaluating plant germplasm for resistance to whitefly was developed based on antibiotic factors. A testing procedure was established to provide a repeatable protocol for evaluation of lettuce germplasm for evaluation of SLWF feeding. Procedures were established for evaluation of SLWF feeding, honeydew contamination, and sooty molds contamination in alfalfa.

E.5 Identify resistant germplasm to SLWF and associated viruses and plant disorders.

High levels of resistance to SLWF were not found in any crop species or cultivars tested. Evaluation of 15 cotton varieties for resistance to SLWF resulted in no significant differences among varieties in 1993 and 1994. Differences were detected among 12 melon varieties in ovipositional rate, nymphal numbers, adult survivorship in field trials, and greenhouse lifetable studies. Significant differences were detected among 12 broccoli cultivars for SLWF colonization preference.

E.6 Conduct plant breeding studies to select SLWF resistant plant germplasm.

Breeding lines were investigated for alfalfa. Half-sib "families" of alfalfa from a genetically diverse germplasm pool were evaluated for SLWF colonization and damage. Several crosses produced lines that had fewer whitefly immatures and less stickiness from honeydew. Selections are continuing along lines of positive response.

Reports of Research Progress
Section F. Integrated Techniques, Approaches, and Philosophies
Co-Chairs: Donald A. Nordlund and Dennis Kopp

Investigator's Name(s): J.C. Allen[1], T.R. Fasulo[1], D.J. Schuster[1], P.A. Stansly[1], D.Byrne[2], J.F. Paris[3], T.M. Perring[4], D.G. Riley[5], C.G. Summers[6].

Affiliations & Locations: University of Florida[1], University of Arizona[2], California State University Fresno[3], University of California, Riverside[4], Texas A&M University[5], University of California, Davis[6].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1994.

Large Scale Cropping Patterns in Relation to Reproduction and Movement of Silverleaf Whitefly

1. Development of Spatiotemporal Models of SLW in Cropping Systems.

OBJECTIVE: Develop models of SLW movement and reproduction in a crop-grid spatial resource system so that the effect of different crop systems can be studied.

A movement and reproduction model in a grid system has been developed in which the crop system can be varied. The dispersal of SLW in this system is modeled by a general dispersal function, e.g., a normal distribution, and a bimodal trivial flier/migrator function have been tried. The bimodal distribution has been suggested by work of D. N. Byrne at U of AZ. The simulations thus far suggest that crop patterns in relation to wind are very important in determining SLW abundance in an area, and that spatial as well as temporal patterns and crop varieties should be considered.

2. Studies of Existing Agricultural Crop Systems Where SLW is a Problem.

OBJECTIVE: Classify and map crops in existing agricultural systems from Landsat data on the San Joaquin, Imperial and Lower Rio Grande (LRGV) Valleys.

Landsat subscenes of the San Joaquin Valley south of Fresno, CA for 1993 have been classified by discriminant analysis and an isoclass method using the MIPS software package. It appears that the isoclass method followed by editing and majority filtering is best. J. F. Paris at CSUF is assisting with this technology. We import these classified images into the simulation package in MATLAB as ascii files which are used to drive the simulations. We are obtaining Landsat data for 1994-5 on the San Joaquin, Imperial and LRGV for classification and comparison of these crop systems in relation to SLW.

3. Whitefly Knowledgebase Development

OBJECTIVE: Develop a computer knowledgebase package for distribution to extension agents and growers in SLW infested areas.

A whitefly knowledgebase for IBM-PC compatibles has been developed by T. R. Fasulo at UF in cooperation with scientists from AZ, CA, FL, NC and TX. The program (WHITEFLY) can be run in a DOS environment and does not require WINDOWS. It is now being distributed ($30 + $5 Shipping) with documentation by: Formedia, Inc., 448 W 16th St., 3rd Floor, N.Y., 10011, Ph.: (212) 675-6444. T. R. Fasulo may be reached at (904) 392-1901 ext 136 or by e-mail at: fasulo@gnv.ifas.ufl.edu.

We would like to acknowledge the USDA NAPIAP Program for its support of these studies.

Investigator's Name(s): S.L. Birdsall, D. Ritter, and P.L. Cason.

Affiliations & Locations: Imperial Valley Agricultural Commissioner and Whitefly Program Coordinator, respectively, El Centro, CA.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1991 - 1994.

Economic Impact of the Silverleaf Whitefly in Imperial Valley, California

The silverleaf whitefly (SLW) *Bemisia argentifolii* Bellows & Perring, a newly described whitefly species in the United States, has caused extensive losses in Southern California since it was first recognized as a pest in 1990 to 1991. The broad host range of cultivated crops, ornamentals and weeds has made the SLW particularly difficult to control as well as contributing significantly to the adverse economic impact on the agricultural community. Dollar losses and associated reductions in agricultural employment are shown in the following table for the years 1991 to 1994.

	Losses in			Reduction in	
Year	Crop Value	Private Sector Sales	Personal Income	Direct Employment No.	Direct and Indirect Employment No.
1991-1992[1]	121,163,092	196,852,408	27,936,441	3,139	5,395
1992-1993[2]	100,497,225	172,152,282	24,560,743	2,787	4,773
1993-1994[3]	106,589,663	182,395,938	29,157,250	3,258	5,196
Totals	328,249,980	551,400,628	81,654,434	9,184	15,364

[1] May 1991 to April 1992
[2] May 1992 to Jan 1993
[3] May 1993 to April 1994

Tabulated losses are for apiary products, vegetable and melon crops, field crops and cotton. The major contribution to the incurred losses is the reduction in planted acreages of melons, cotton, alfalfa and winter vegetable crops.

Investigator's Name(s): R. Diaz-Plaza, Ch. J.L. Ramirez, and B.W. Aviles.

Affiliations & Locations: INIFAP, Centro de Investigacion Regional Sureste, Apdo. post. #13., Mérida, Yucatán, México.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: Research conducted from 1991-1992.

Integrated Control of Virus Transmited by Whitefly in Tomato

For prevention or reduction in virus infection and severity in tomato, eight practices were used together in farmer's field in comparison of traditional practices (only used insecticides). The practices tested were:

- Seedling protection with a mesh.
- Use of corn as a barrier around the field.
- Increase of 35% of tomato population density.
- Removal of infected plants when they appear during 30 days after transplanting.
- Increase of the fertilization in 35%.
- Weekly application of endosulfan 35%.
- Use of sticky trap.
- Elimination of wild weeds in the field and 5 meters around it.

The practices tested permit to obtain 769% more than traditional practices (2.6 ton. per ha.). Meanwhile, virus incidence was 51% and the severity index was 2 in tested plot (arbitrary scale was 1=healty to 6=stunty plant and no production), in traditional plot were 98% and 5, respectively.

Investigator's Name(s): Peter Ellsworth[1,2], Jonathan Diehl[1,2], Timothy Dennehy[2], and Steve Naranjo[3].

Affiliations & Locations: University of Arizona, Maricopa Agricultural Center, Maricopa, AZ[1]; University of Arizona, Department of Entomology, Tucson, AZ[2]; and USDA-ARS Western Cotton Research Laboratory, Phoenix, AZ[3].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1994.

Development and Delivery of Sampling Plans for Sweetpotato Whiteflies in Cotton

University of Arizona and USDA-ARS Western Cotton Res. Lab. personnel collaborated on the development of sampling and threshold recommendations for sweetpotato whiteflies in cotton. We recommend sampling adult whiteflies on the underside of the fifth main stem node leaf of at least 30 plants per field (15-leaves from each of 2 sites). Using a binomial scheme in which a leaf with 3 or more adult whiteflies is deemed "infested", the percentage of infested leaves can be converted to the mean number of adults/leaf. An action threshold of 5-10 whitefly adults/leaf is recommended for initiating application of insecticides. These plans were presented in a trifold-bulletin and published as Univ. of Ariz. Cooperative Extension IPM Series Number 2, *Sampling Sweetpotato Whiteflies in Cotton*. Three thousand copies of this trifold were distributed within Arizona, and hundreds more were disseminated in California and the Mexicali region of Northern Mexico. Workshops were held in cotton growing areas throughout Arizona to introduce this sampling technique to growers and pest control advisers. These plans were implemented by Cooperative Extension personnel within 8,000 acres of cotton in Maricopa County, Arizona and have been widely used by growers within the Mexicali region of Mexico.

Investigator's Name(s): Peter Ellsworth[1,2], Jonathan Diehl[1,2], Steve Naranjo[4], Steve Husman[3] and Timothy Dennehy[1].

Affiliations & Locations: University of Arizona, Maricopa Agricultural Center, Maricopa, AZ[1]; University of Arizona, Department of Entomology, Tucson, AZ[2]; Maricopa County Cooperative Extension, Phoeniz, AZ[3] and USDA-ARS Western Cotton Research Laboratory, Phoenix, AZ[4].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1994.

Establishment of Integrated Pest Management Infrastructure: A Community-Based Action Program for Sweetpotato Whitefly Management

Extension activities within the Laveen-Tolleson Community Pest Management Program during its second year of existence emphasized:

(1) education of growers and pest control advisers about a new sampling technique for whiteflies in cotton,

(2) validation of sampling plans within 8,000 acres of cotton to insure the reliability of these plans for commercial use, and

(3) implementation of these sampling plans within commercial cotton fields including documentation of the limitations of the techniques used.

Monthly meetings were held within the community to discuss whitefly biology and management. Discussions focused on the need for infield monitoring for whiteflies, the properly timed application of efficacious materials for whitefly management, and the potential for avoidance of whitefly populations. In particular, the risk of whitefly infestations may be reduced by the observance of uniform planting and termination dates, management of whiteflies in other crops, observance of good agronomic practices to keep the crop stress free, compaction of crop season and maintenance of timely sanitation practices.

Sampling plans were validated within 8,000 acres of cotton in this community. Overall, these plans were found to be robust for making management decisions. Validation procedures are described in an abstract by Naranjo *et al.* (Section A).

Sampling plans for whiteflies were implemented within 190 grower fields, representing about three-quarters of the total cotton acreage within the community. Fields were sampled weekly. Samplers were managed by extension personnel and reports were provided to the pest control adviser responsible for each field. On the average, the total time to sample each field (30 leaves/field) was less than 13 minutes. Neither sampler experience (0 - 2 years experience) nor time time of day (6:00 a.m.–5:00 p.m.) had a significant effect on sampling outcome. A binomial sampling scheme using a tally threshold of 3 whiteflies/leaf provided the same decision as did using the actual mean number of whiteflies/leaf 96% of the time. The total cost of the sampling program was $2.35/acre, $0.35 of which was provided by participating growers.

Investigator's Name(s): T.R. Fasulo[1], J.C. Allen[1], T.S. Bellows[2], G.A. Evans[1], M.L. Flint[2], P.B. Goodell[2], T.X. Liu[1], R.L. Nichols[3], J.W. Norman[4], T.M. Perring[2], D.G. Riley[4], A.N. Sparks[4], P.A. Stansly[1], N.C. Toscano[2].

Affiliations & Locations: University of Florida[1], University of California[2], Cotton Incorporated[3], Texas A&M University[4].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: January 1994 through October 1994.

WHITEFLY: A Hypertext Computer Knowledgebase on Whiteflies Damaging to Crops & Ornamentals

This is a computerized, hypertext knowledgebase on four whitefly species damaging to agricultural and ornamental crops. These include the sweetpotato whitefly, *Bemisia tabaci* (Gennadius); the silverleaf whitefly, *B. argentifolii* Bellows & Perring; the bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman); and the greenhouse whitefly, *T. vaporariorum* (Westwood). The computer program was funded by the USDA Extension Service, NAPIAP. The knowledgebase contains detailed information on identification, biology, life cycle, damage, management, and control. It also includes literature references in every area of whitefly research. The knowledgebase provides a graphical key to help users identify which of the four species is causing problems.

While the knowledgebase itself was developed at the University of Florida, the information, graphics and photographs contained in WHITEFLY came from experts in California, Florida, North Carolina, and Texas. While WHITEFLY contains management information specific to several diverse geographical locations in the United States, it has a feature, called Reader's Notes, that allows users to add and edit their own information on every screen. This information can also be saved to an ASCII file for printing.

WHITEFLY uses a hypertext authoring system that allows users to select pop-up definitions for hundreds of entomological and other scientific terms. Hypertext also allows quick access to scores of full screen VGA graphics, color and scanning electron microscope photographs. Knowledgebase users can reach the desired information without being constricted to a menu structure. In addition, users can leave permanent electronic bookmarks throughout the knowledgebase to quickly return to any screen.

WHITEFLY will run on any IBM-compatible system with a VGA monitor and video card, 640 kilobytes of RAM, and 4.7 megabytes of available hard disk space. Text can be printed to any printer, but printing graphics requires a Hewlett-Packard LaserJet or compatible. The knowledgebase comes with a self-install program that tests for the above requirements, creates the necessary directories, and then transfers the files to the hard drive.

The knowledgebase is available on 3.5" or 5.25" diskettes, and is shipped in a white 9"x7" vinyl folder with printed documentation. It can be ordered through Formedia, 448 West 16th Street, 3rd Floor, New York, NY 10011, USA for $30 plus $5 shipping and handling. International orders should write for shipping costs or call (212) 675-6444 for information.

Investigator's Name(s): P. B. Goodell[1], L. D. Godfrey[2], M.L. Flint[2], W. J. Bentley[1], R. Coviello[3], P.C. Ellsworth[4], and T. Dennehy[5].

Affiliations & Locations: University of California: Kearney Agricultural Center[1], Davis[2], Fresno[3]; and University of Arizona: Maricopa Agricultural Center[4], Tucson[5].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1/94 through 12/94.

Development and Delivery of a Whitefly Train-the-Trainer Program

As silverleaf whitefly becomes more widely distributed in the San Joaquin Valley, the demand by the public for information has increased. This demand for information has historically outstripped the ability of extension to respond. In an effort to increase the number of whitefly disseminators, a training program was developed. The purpose of this program was to: 1) develop curricula and educational materials to support instructor training; 2) provide training to clientele about silverleaf whitefly including identification, management, biology, and economic impact; and 3) develop a network of qualified instructors. This project was supported with funding from NAPIAP and is a result of collaborative efforts of scientists at the University of California, Davis and Riverside, and the University of Arizona.

The goal was to develop a group of extenders who could provide the front line, elementary presentations to civic groups, garden clubs, city councils, service clubs, or any group who requested a short presentation on whitefly. It was not intended to develop accomplished whitefly experts, but to increase the number of people who could make general whitefly presentations and provide accurate information.

The centerpiece of the project was the development of a resource manual titled, "Whiteflies in California, A Resource for Cooperative Extension Advisors". This nine section reference manual contains pertinent background information about whiteflies in general but provides focus on silverleaf whitefly. It contains information on identification, management, biology, ecology, and history. It was written by Dr. M.L. Flint with input and review by 12 experts in the field. Resource material for the trainers included two camera ready fact sheets (Silverleaf Whitefly, Pest Notes #1 and Greenhouse Whiteflies, Pest Notes #2), examples of color brochures for meetings, and an optional slide set. In addition, a color key to common whiteflies, specific management guidelines (excerpted from UC IPM Pest Management Guidelines), key references, and a list of key whitefly experts was provided. Approximately 100 copies were distributed. The manual was modified to accommodate Arizona conditions by inserting Arizona Advisory pages containing specific information and guidelines.

Training activities involved both lecture and hands-on activities. Biology, ecology, and identification skills were provided. Live specimens of various whiteflies as well as natural enemies were available for examination. Sampling and problem solving activities were provided. Research and situation updates were conducted. The Whitefly Knowledge Base was available for individual exploration. Four training workshops were conducted in California and Arizona. Over 30 hours of training was provided to 100 Cooperative Extension advisors, agents, and other professional trainers. The multiplier effect is not known.

Investigator's Name(s): Raúl León López, Max Cervantes and Benjamin Sánchez.

Affiliations & Locations: INIFAP y SANIDAD VEGETAL-SARH, Mexicali, B.C. México.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1993 - 1994.

IPM Actions and Practices in Cotton

In 1991 the SLWF caused severe damage to cantaloupe, watermelon and sesame during the summer. Economic loss was estimated at 20 million dollars. This time cotton damage was minimal because the pest showed a strong preference for the other crops attacked.

However, in 1992, the average yield of 19,600 hectares was 2.22 bales/ha, which was approximately 55% below the expectations. The estimated economic loss was in the order of 18 millions dollars. It is important to mention that no hectares were planted to cantaloupe, sesame or watermelon during the summer of 1992. So, migration of the SLWF from the spring melon was directed mainly toward the cotton fields. This is our understanding why no damage was caused by the pest in cotton crops in 1991 but a strong one was present in 1992.

With this experience the growers planted to cotton in 1993 only 719 hectares. A pilot program was designed to control pest in 24 commercial fields (390 hectares). The average yield was 5.06 bales/ha using only 3 insecticide applications. It was observed the convenience of doing insecticide edge treatments to reduce early infestations.

Based on the 1993 experience, in 1994 growers planted 12,500 hectares to cotton. The average yield was 5.2 bales/ha with only 3 insecticide applications.

The most important IPM actions and practices involved in this success has been:

1. Pruning of roses in urban areas and destruction of the weeds sowthistle and malva in agricultural areas during January and February to reduce overwintering SLWF population.

2. Massive releases of lacewing Chrysopa in commercial fields of wheat, cantaloupes, watermelon and squash during the spring to increase its population in a regional level.

3. Important is the shredding and plowdown of spring melons, squash and watermelon immediately after harvest to avoid the dispersion of SLWF adults to cotton fields and other crops.

4. Cotton planting date no later than March 31 and defoliation late in August or early in September.

5. During the cotton growing season a key action was a "regional monitoring of adult SLWF infestations in 40 commercial fields." Sampling was made in a weekly basis from May to August. Sample per field consisted of 60 leaves selected from 3 sampling sites (two in the edge and one in the center of the field). Selection of the leaf in the upper part of the plant, counting of adults and action threshold used was made according to the sampling plan reported by Peter Ellsworth et. al, IPM Series-Number 2, Cooperative Extension, University o Arizona.

The data collected every week from the 40 fields was shared timely with the PCA to assist them in deciding the best chemical control action for the 12,500 hectares planted. The highest acreage per week that required insecticide treatment was about 50%. Most of the time mixture of two insecticides was used, being the most effective Danitol + Orthene and Hostathion + Orthene (Hostathion = Triazofos).

Investigator's Name(s): Eric T. Natwick.

Affiliations & Locations: University of California Cooperative Extension, 1050 E. Holton Road, Holtville, CA 92250.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1994.

IPM and Whitefly Control from the Growers' Perspective

How do we develop a grower acceptable IPM program focused on whitefly management? All growers in a well defined geographic area, encompassing the total crop production system, must be actively be involved in the planning and implementation of an IPM program. Through a community-wide effort, the growers accept ownership and responsibility to each other for development, implementation, and policing of the IPM program.

What are the roles of researchers and extension educators in the development and implementation of an area-wide whitefly IPM program? Researchers must supply the technical support for the program through basic research and practical applied research. Research should be based upon an understanding of the cropping system in a defined geographic area. The growers must have input into research, both economically and based on the practicality of whitefly management practices. Growers will only implement practices that they perceive to be economically feasible. The extension personnel must interface with the grower and the research communities to communicate the applied research needs, advise the growers of research based components for the development of an IPM program, and advocate implementation.

What IPM program components need to be developed or implemented?

- **Whitefly Population Growth and Abundance.** To implement an IPM program, we must be able to measure whitefly population abundance and predict population growth. Whitefly sampling methods for use with economic action thresholds are vital to implementing IPM programs.
- **Cultural Practices.** Cultural practices are often the first whitefly control measures to be recognized and implemented by growers. Whitefly cultural control practices include: 1) crop sequencing, 2) host free or host reduction periods, 3) shortened crop production seasons, 4) post-harvest sanitation practices, 5) selective weed control, 6) mechanical control, 7) trap crops, and 8) crop selection.
- **Host Plant Resistance.** Crop plants that are highly resistant to silverleaf whitefly and whitefly transmitted virus diseases can be used in an IPM program to help manage insecticide resistance, reduce pesticide pressure on beneficial insects, and be grown during host reduction periods.
- **Biological Control.** Research on the systematics and biology of potential candidate species of parasitoids, predators and entomopathogenic fungi for use against the silverleaf whitefly is critical to the development of control strategies. Biological control of silverleaf whitefly is complicated in an annual cropping system and by our current reliance of broad spectrum insecticides for control of the pest. Annual cropping systems with dense populations of migrating whitefly adults require quick control response by growers. Too often, the only viable control measures are the use of broad spectrum insecticides hindering the establishment of parasitoids and parasites. Augmentative release of large numbers of whitefly biological control agents in fields is not yet logistically nor economically feasible. Augmentative applications of entomopathogenic fungi as biological agents are being implemented in some countries. For control, entomopathogenic fungi must be adapted to the climatic conditions of a given crop production area.
- **Chemical Control.** Insecticides are not excluded from IPM programs, but must be used wisely for control of whitefly populations or other insect pests. The dependence on broad spectrum insecticides for whitefly control to the near exclusion of other IPM program components is a formula for disaster. Insecticides are the tools most growers use for silverleaf whitefly control today due to the slow development and implementation of biological control and host plant resistance to this pest and virus diseases it transmits.

Investigator's Name(s): John W. Norman, Jr., Alton N. Sparks, Jr., and David G. Riley.

Affiliations & Locations: Texas Agricultural Extension Service & Texas Agricultural Experiment Station, Weslaco, Texas.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1991 - 1994.

An Integrated Approach to Sweetpotato Whitefly Management in the Lower Rio Grande Valley of Texas

Sweetpotato whiteflies (SPW) first caused economic damage to crops in the Lower Rio Grande Valley (LRGV) of Texas in the summer of 1990. Cotton and then fall vegetables were impacted by SPW infestations. The spring of 1991 again saw severe damage to vegetables and cotton throughout most of the LRGV. By the end of August, 1991, growers, commodity organizations, and Extension and Research scientists formed a Sweetpotato Whitefly Task Force to try to manage SPW in the LRGV. The immediate result of the first few sessions of the SPW Task Force was the formulation of a set of SPW management guidelines based on the biology of the pest, crop production practices in the LRGV and the experiences of local producers and scientists. The guidelines were publicized on radio, television, newspapers and various newsletters throughout the LRGV from late August through the present date to try to encourage producer and consultant adoption. Results of the guidelines have been rated as cautiously successful to date. The LRGV has not experienced an SPW infestation/damage or economic impact anywhere near the proportions recorded in 1991.

TABLE F. Summary of Research Progress for Section F - Integrating Techniques, Approaches and Philosophies in Relation to Year 3 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
F.1 Risk Assessment.	Yr. 3: Operate risk assessment system. Validate risk assessment estimates. Expand to other pests. Collate multi-location results. Interface with IPM programs and crop loss assessment.	X		Progress in this approach has been made in the following areas: * A broader understanding of virus-whitefly plant interaction has been developed. * An increased understanding of the role of different host plants in whitefly population development has been accomplished. * An increased understanding of whitefly host plant resistance has developed. * Whitefly sampling techniques to monitor population development and dispersion have been developed, improved and validated. * There is an increased understanding of insecticide resistance management in whitefly management programs.
F.2 Spatial Analysis and GIS.	Yr. 3: Run and validate system performance. Interface system with ecosystem modeling activity. Interface system with existing IPM networks.	X		Progress in this approach has been made in the following areas: * An informal network of scientists interested in the development and application of remote sensing applications to whiteflies has formed. * Satellite crop map information is being coupled with pest management issues related to spatial distribution. This information is being used in IPM implementation programs and for crop sequencing in area wide management approaches.
F.3 Ecosystem modeling.	Yr. 3: Interface with spatial analysis. Couple crop model with spatial data.	X		Progress in this approach has been made in the following areas: * An age dependent model as it relates to the role of natural enemies is under development and being evaluated. * GIS technology has been developed and is bring applied to models to evaluate and predict whitefly population development and dispersal within certain Agroecosystems. * Field Sampling is being used to validate prediction capabilities of whitefly population models.
F.4 Networks.	Yr. 3: Teleconference on SPW program internationally. Begin transfer of GIS to extension applications.	X		Progress in this approach has been made in the following areas: * E-Mail transmission of information is being used, instead of teleconferencing. * WRCC-87 will take leadership in the development and coordination of an electronic delivery system for whitefly information. * A WWW home page establishment is planned to enhance information exchange. * Pest alert database is available via gopher at the University of Florida and includes whitefly and virus information. * Implementation and new management technologies are being shared with scientists in other countries. This was demonstrated by the broad participation, information sharing and networking of US scientists in the BARD International Workshop in Shoresh, Israel, October 2-7, 1994.

Research Approaches	Goals Statement	Progress Achieved Yes	Progress Achieved No	Significance
F.5 IPM Program Implementation.	Yr. 3: Maintain and expand the foundational support system and continue cooperative networking needed for the expansion of IPM program implementation.	X		Progress in this approach has been made in the following areas: * Area wide management programs have been initiated in Arizona, California and Texas. Each program is being expanded in geographic area and crops covered. * A national effort has been made to distribute and share extension developed whitefly management educational publications and resource materials produced by scientists in Arizona, California, Florida and Texas. * Through local leadership and team building, whitefly management committees and task forces are being formed to address area wide management approaches. * During the past year, a train the trainer program has been developed and implemented in California and Arizona. Implementation is likely in other states. * WHITEFLY hyper-test knowledge base has been developed and is presently available for a nominal fee. This can be used as a teaching tool or a data resource for crop consultants agriculturists or producers. * Satellite crop map information is being coupled with pest management issues related to spatial distribution. This information is being targeted to IPM implementation programs as they relate to crop sequencing in areas wide management approaches.

Research Summary
Section F: Integrated Techniques, Approaches and Philosophies(1)
Compiled by: Dennis D. Kopp, Donald A. Nordlund and John Norman

As we move into the fourth year of this National Research and Action Plan considerable progress is noted regarding the development and delivery to growers of management and control methodologies for the Silverleaf Whitefly. Whitefly management committees and programs have been organized in the Lower Rio Grand Valley of Texas, Phoenix and Yuma areas of Arizona, the Imperial and San Joaquin Valleys in California. The most successful programs are those with a broad base of stakeholders (scientist, grower, community leaders and residents) that are participants in the process. The networking of scientists with a broad array of community leaders is needed to develop action plans to address whitefly management as a part of area wide Integrated Pest Management (IPM) programs. Progress has been made on the following research approaches:

F.1 Whitefly Risk Assessment: Operate risk assessment system. Validate risk assessment estimates. Expand to other pests. Collate multi-location results. Interface with IPM programs and crop loss assessments.

Several types of risk are addressed in this research approach. The base risk which drives all pest management activities is risk of economic loss to the agricultural producer. At the plenary session of the 3rd progress review a suggestion was made that it would be wise to complete a National Assessment (or) Evaluation of the Economic Impact of Whiteflies to United States Agriculture. An assessment of the economic risk this insect poses to US agriculture could be a very important and useful document, for accountability purposes, in the justification of the expenditure of research funds and scientist time.

A second type of economic risk faced annually by producers is will his/her susceptible crop sustain economic loss this season. Factors such as crops patterns, crop sequencing, and direction of prevailing winds all influence this risk factor. In addition to direct feeding damage there is also the risk of whitefly vectored crop disease. Over the past 2 years a broader understanding has been developed in: 1) virus-whitefly plant interactions, 2) the relationships and interactions that exist between crop plants and viruses, and 3) an increased understanding of whitefly host plant resistance. Progress in the understanding of these risk, economic, and plant/insect disease relationships has been accomplished by the research and cooperative interactions of scientists in Arizona, California, Florida, and Texas.

Health risk issues due to pesticide usage to control whitefly is a consideration of applicators, producers, crop consultants, and concerned citizens. Antagonistic situations can develop between agricultural producers and community groups where agricultural lands are located adjacent to urban areas. The community based action program based upon IPM principles near the Arizona communities of Laveen-Tolleson is in it s second year. This type of community interaction provides an educational forum and an opportunity for people to develop a broader understanding of all positions by working together for the purpose of problem solving and compromise and to arrive at an acceptable solutions. These dialogues provide for the development of new understandings by all parties of agricultural pest management needs and pubic pesticide concerns.

F.2 Spatial Analysis and GIS: Run and validate system performance. Interface system with ecosystem modeling activity. Interface system with IPM networks.

Progress is being made toward the refinement of a whitefly model that is reflective of population development and movement through cropping systems. Whitefly sampling techniques to monitor population development and dispersion has been developed, improved and validated. During the last growing season, scientists in Arizona developed extensive field trials to validate an economic threshold and action level in cotton. Additional work is being done by scientist in Yuma, AZ and Weslaco, TX to refine the whitefly economic threshold in vegetable crops. Simulation models, thus far, suggest that crop patterns in relation to wind are very important in determining SLW abundance in an area; as well as the spatial and temporal cropping patterns; and the susceptibility of crop varieties to whitefly damage. These data are being incorporated into working models.

During this years progress review, an informal network of scientists interested in the development and application of GIS and remote sensing applications to whitefly management was formed. This group discussed opportunities for future cooperation and information exchange. Satellite crop map information is being coupled with pest management issues related to spatial distribution. Landsat sub-scenes of the San Joaquin Valley, south of Fresno, CA, have been classified by discriminate analysis to develop crop maps of the area. These technologies

will be expanded to the Imperial Valley, Lower Rio Grand Valley in Texas and selected cropping areas in Florida. This information is being developed to help in the implementation of IPM programs as they relate to crop sequencing leading toward areas wide management approaches.

F.3 Ecosystem modeling: Interface with spatial analysis. Couple crop model with spatial data.

An age dependent model as it relates to the role of natural enemies is under development and being evaluated. Dispersal models of whitefly movement within and between fields are being developed through the joint efforts of David Byrne in Arizona and Jon Allen in Florida. These data will allow the application of GIS technologies to models for the evaluation and/or prediction of whitefly population development and dispersal within Agro-ecosystems. Field Sampling in the Lower Rio Grand Valley in Texas, Yuma, Arizona the Imperial and San Joaquin Valleys of California is being used to validate and improve the prediction capabilities of whitefly models.

F.4 Networks: Teleconference on SLW program internationally. Begin transfer to GIS to extension applications.

The use of E-Mail transmission of information has taken preference over teleconferencing. The transfer of GIS imagery may be delivered via digital television signals transmitted across a satellite bridge, but no immediate use of teleconferencing is planned. Land Grant scientists in WRCC-87 indicated an intent to take leadership in the development and coordination of electronic delivery systems of whitefly information. A WWW home page establishment is planned for 1995 to enhance information exchange. At present a "pest alert" database is available via gopher at the University of Florida which includes whitefly and virus management information. Also a BBS on whitefly information is available in California.

Implementation and new management technologies are being shared with scientists in other countries. At the 3rd progress review, scientists from 9 countries in addition to the US were in attendance. Community based management system and train the trainer programs as developed by Arizona and California scientists are being used by INIFAP scientist and extension personnel in the Mexicali Valley of Mexico. The integration of non-chemical management practices into a traditional pesticide based control programs by INIFAP scientists in Yucatan, Mexico has demonstrated substantial reduction of virus incidence in tomatoes and large increases in crop yield. In early October 1994, there was broad participation of US scientists sharing information and networking at the BARD International Workshop in Shoresh, Israel.

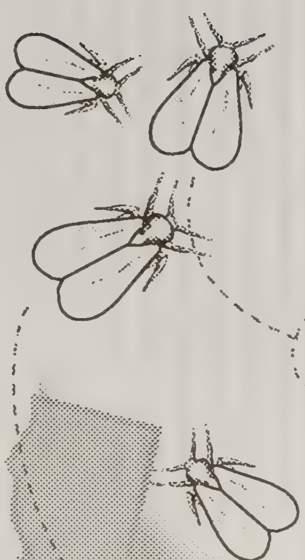
F.5 IPM Program implementation: Maintain system and continue to expand to other pests.

Area wide management programs have been initiated in Arizona, California, and Texas. Each program is being expanded in geographic area and crops covered. Through local leadership and team building, whitefly management committees and task forces are extending their roles to address area wide pest management approaches in multi-crop systems in the San Joaquin and Imperial Valley of California, in several areas in Arizona and in the Lower Rio Grand Valley of Texas. A national effort has been made to distribute and share extension developed whitefly management educational publications and resource materials produced by scientists in Arizona, California, Florida and Texas.

During the past year, a "train the trainer" program has been developed and implemented by scientists in California and Arizona. At present, the information developed and used in this educational program are being shared with and distributed to scientist in other States and Mexico.

WHITEFLY hypertext knowledge base for IBM-PC compatibles has been developed by T.R. Fasulo at the University of Florida. This effort was accomplished within the last year with the cooperation, information, slides, and graphics from scientists in Arizona, California, Florida, North Carolina and Texas. This program is presently available for $30 from Formedia, Inc. Ph. (212) 675-6444. This can be used as a teaching tool or an information resource for crop consultants agriculturists or producers. For further information on this program, T.R. Fasulo may be reached at (904) 392-1901 ext 136 or by e-mail at: <fasulo@gnv.ifas.ufl.edu>

Footnote:
(1) The information in this Research Summary is based upon information extracted from Section F abstracts received prior to the deadline of February 14, 1995, poster presentations, formal presentations and informal gatherings for information exchange during the 1995 meeting in San Diego, CA. Information whispered to Connie Chung was not included in this summary.



COOPERATIVE ACTIVITIES IMPROVE SILVERLEAF WHITEFLY MANAGEMENT

		LAND GRANT UNIVERSITIES				PRIVATE ORGS.				STATE GOVT			FEDERAL GOVT		INTL. COMM.
		University of Arizona	University of California	Texas A&M University	University of Florida	Cotton Inc.	Calif. Cotton Pest Control Bd.	Imperial Valley WF Committee	IRAC	County Agric. Commissioner	Calif. Dept of Food & Ag	Cal State Univ., Fresno	USDA-An.Plnt.Hlth.Inspctn.Svc.	USDA - ARS	USDA - CSREES	USDA - OICD BARD
RESEARCH	Host plant resistance	□	■	■	□	□	□	□	□	□	□	□	□	■	□	□
	Economic thresholds on cotton	■	■	■	□	■	□	□	□	□	□	□	□	■	□	□
	Resistance management	■	■	■	□	■	■	■	□	□	□	□	□	□	□	□
	Spatial & temporal distribution	■	■	■	□	■	□	□	□	■	■	□	■	□	□	□
	Biological control	■	■	■	■	□	□	□	□	□	■	□	■	■	□	□
	Geographical information systems	■	■	■	■	□	□	□	□	□	□	■	□	□	□	□
	Organize conferences & symposia	□	■	□	□	□	□	□	□	□	□	□	□	■	■	■
EXTENSION	Train the trainer	■	■	□	□	□	□	□	□	□	□	□	□	□	■	□
	Whitefly knowledgebase	■	■	■	■	□	□	□	□	□	□	□	□	□	■	□
	Regional bulletin	■	■	■	■	□	□	□	□	□	□	□	□	□	■	□
	Regional slide set	■	■	■	■	□	□	□	□	□	□	□	□	□	■	□
	Development of sampling method	■	■	□	□	□	□	□	□	□	□	□	□	■	□	□
	Development of WF mgmt. groups	■	■	■	□	□	□	■	□	■	□	□	□	□	□	□
	Develop, exchange & distribute educational materials	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□

Poster developed by Peter B. Goodell, *University of California* ; Peter Ellsworth, *University of Arizona* ; John Norman, *Texas A&M University* ; John Allen, *University of Florida* ; Dennis Kopp, *Cooperative State Research, Education and Extension Services, USDA.*

This poster was developed with the information available and every attempt was made to be inclusive. If your project or agency has been overlooked, please contact Peter Goodell (209/ 891-2500) for inclusion in the next version.

Overview and Recommendations

A. Ecology, Population Dynamics, and Dispersal

Continuing research on the many whitefly host plant interactions, numbers of plant hosts and potential reproductive capacities in relation to various hosts emphasizes the complexity of the ecological relationships of the silverleaf whitefly. Some information is beginning to be developed on predator species and seasonal occurrence of predators, but quantification of their impact on silverleaf whitefly population is unknown.

Sampling methods for silverleaf whiteflies have been developed for cotton and melons and have been extremely effective and useful in developing action thresholds. Thresholds are continually being refined, but their value in reducing insecticide overuse and reducing costs is evident. This work needs to be expanded to include other major crops. Silverleaf whitefly dispersal and movement continues to be a population expansion factor in intercrop-population buildup. Factors affecting dispersal have been difficult to isolate, but the high priority of this work suggests expansion of effort in this area. Few dispersal studies have been done outside desert ecosystems which represents a small portion of the silverleaf whitefly problem areas.

<u>Recommendations</u>

1. Quantify the contribution of cultivated and field hosts to silverleaf whitefly population dynamics.

2. Adult, egg and nymph sampling plans need to be developed for crops other than melons and cotton.

3. Action and economic thresholds need to be developed for all major crops.

4. Dispersal, movement, behavior research needs additional emphasis.

B. Fundamental Research–Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Vector Interactions

Whitefly adult and nymph feeding behavior and stylet positioning, oviposition site selection and relationships to plant leaf morphological characteristics as well as salivary enzyme identification is leading to several hypotheses regarding plant alteration possibilities that could adversely affect whitefly population development.

Studies of pupal and last nymph instar morphological characteristics were determined inadequate alone to separate species. DNA sequence similarity studies have supported a hypothesis that a *Bemisia* complex exists. Mechanisms involved in toxigenic effects of whitefly such as irregular ripening in tomato and silverleaf in squash have not been resolved, but promising genetic and molecular approaches may provide information identifying causes. Whitefly endosymbionts and their role in whitefly biology are poorly understood, several types have been identified that appear biotype related. Endosymbiont involvement in production of the whitefly sugar trehalulose is postulated and further illucidation may suggest a potential area of focus for disruption of metabolic pathways. Whitefly transmitted geminivirus induced diseases of vegetable and ornamentals have been documented in Florida, Hawaii and Mexico. The whitefly B biotype efficiently transmits bean golden mosaic virus. PCR techniques have been developed for identifying geminiviruses.

<u>Recommendations</u>

1. Investigate the potential of chemical, biochemical, genetic or other methods of disrupting aspects of whitefly feeding and oviposition and endosymbiont relationships.

2. Identify and quantify natural enemy impact on whitefly populations.

3. Characterize the *Bemisia* complex.

4. Intensify research activity on geminiviruses.

C. Chemical Control, Biorationals, and Pesticide Application Technology

Efforts to further evaluate insecticides and biorationals for SLW control among USDA, University and Industry scientists is contributing to the registration or securing of section 18 registrations of several effective insecticides for the control of SLW. Also, efforts to develop effective aerial application technology were continued and are expected to provide improved insecticide spray deposition and efficacy. Significant progress was made in the development and implementation of action thresholds on cotton and melons. Relationships between SLW density and crop yield/quality have also been established for several crops. Techniques to monitor insecticide resistance are being utilized, and baseline data from several field populations in the U. S. and Mexico is being collected. Although preliminary efforts have been made to examine

the genetics of resistance and effects on insecticides on natural enemies, analysis shows the need for expanded efforts.

Recommendations

1. Initiate the evaluation of new and novel chemistries with the most efficient application technology available.

2. Develop laboratory and field bioassays for biorationals, insect growth regulators, and new chemistries with novel models of activity.

3. Determine how timing of insecticide applications (i.e., action thresholds) is affected by differences in activity of chemical, biorational and IGR insecticides.

4. Focus more research on understanding resistance mechanisms, so development of resistant management programs can be initiated.

5. Increase research efforts to improve aerial applications, and better understand interactions between plant dynamics and chemical retention.

D. Biological Control

Increasing research effort is being evidenced in biological control research in 1994 as compared to the 5-year plans reviews for 1992 and 1993. Several large scale parasite release programs have been implemented. Under harsh desert environments results have varied, but releases in the more hospitable San Joaquin Valley and in greenhouses, have been more promising. Availability of natural enemies is not a problem and Aphis, Mission Biological Control Laboratory has increased numbers available for testing. Two fungal pathogens *Beauveria bassiana* and *Paecilomyces fumosoroseus* continue to be promising candidates for whitefly biological control. The taxonomy of whitefly natural enemies continues to need increased research emphasis.

Recommendations

1. Increase field evaluation of indigenous and exotic natural enemies.

2. Reassess and develop effective methods for selection of effective plant hosts in refugia habitats.

E. Crop Management Systems and Host Plant Resistance

Results of research continue to show that crop production inputs, such as irrigation and fertilizer, can influence silverleaf whitefly populations. For example, water stressed cotton plants develop higher populations than nonstressed plants. The underlying reasons for these whitefly-host interactions are unknown but definition of mechanisms involved may provide avenues of investigation that would reveal cultural or other methods of crop manipulation that would be useful in managing whitefly populations.

Exclusion methods such as row covers and screen barriers and repellent reflective mulches have been shown effective in some cropping systems to reduce whitefly populations and disease incidence. Based on increasing knowledge of whitefly host preference, results of several studies suggest that trap crops may also have a role in some crop production systems. Continuing efforts in these areas and determination of the mechanisms involved, for example in repellency and associated whitefly behavior may suggest ways to improve current results and/or suggest new approaches.

The development of whitefly and disease resistant varieties using conventional breeding methodology may be slow to realize, but, when successful, the results provide a socially and environmentally acceptable and effective control method. Current levels of whitefly host plant resistance research, in most cases, is at the screening level to identify resistant germplasm. With most crops, a wide range of whitefly susceptibility has been found. The results suggest a high level of probability that some level of resistance can be found and incorporated into acceptable agronomic types.

Recommendations

1. Determine mechanisms involved in cultural and agronomic crop production practices that influence whitefly populations.

2. Identify crop production systems where exclusion techniques can be economically and agronomically useful. Increase research focus in these areas and develop appropriate methodology.

3. Expand conventional plant breeding approaches to develop whitefly and disease resistant varieties. Initiate studies with new genetic approaches to determine their potential for identifying resistant genes and transfer to acceptable agronomic crop varieties.

F. Integrated Techniques, Approaches, and Philosophies

Communication systems to move current state-of-the-art recommendations, research progress and proposed research to the grower community and other involved in agricultural production is one the most \important aspects of the 5-year

silverleaf whitefly research and action plan. Progress in developing systems to accomplish this goal and move information in a timely fashion to the consumer is notable in the formation several grower oriented management committees in California, Arizona and Texas. Additionally, several informative and useful database systems have been made available through computer networking.

Risk assessments in terms of crop values and impact on the agricultural community and associated environmental impacts are poorly defined nationally. However, GIS, modeling, sampling methodology, landstat applications and other area and regional information gathering systems show promise for development of broad base information exchange and "on time" assessments of whitefly and disease incidence.

Recommendations

1. Continue development of information bases with updated and timely information.

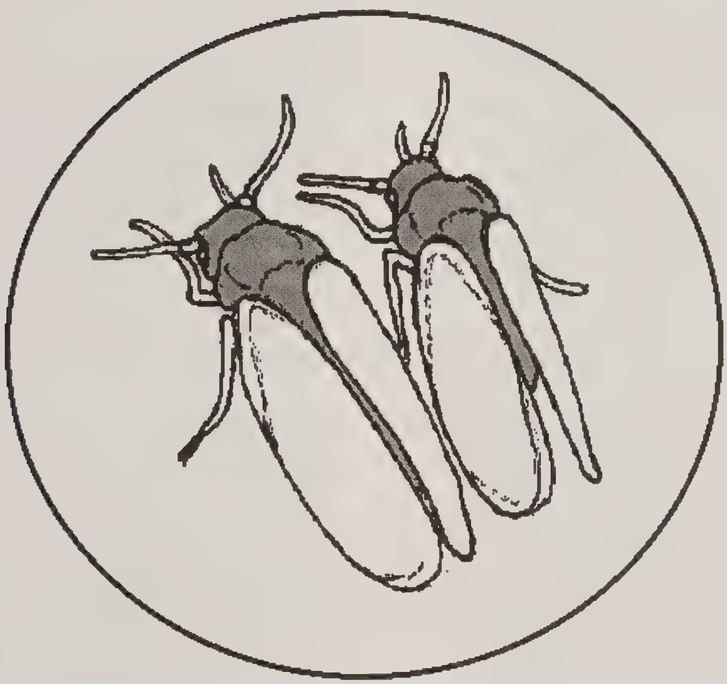
2. Expand efforts in computer based national networking systems for information exchange.

3. Develop systems of data acquisition for crop losses values. Also, associate impact on agricultural communities and losses to associated agricultural commodity support systems such as transportion, warehousing, storage and marketing.

Appendix A

Bibliography of

Bemisia tabaci (Gennadius)
&
Bemisia argentifolii Bellows and Perring



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J. K. Brown

January 1995

In 1986 M. J. W. Cock published "*Bemisia tabaci* - a Literature Survey on the Cotton Whitefly with an Annotated Bibliography". In connection with the 5-year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly", Butler and Henneberry prepared "A Bibliography of *Bemisia tabaci* (Gennadius)" (unpublished) and made it available to participants at the First Annual Review of the 5-year plan held in Tempe, Arizona from 18-21 January 1993. That bibliography included all of Cock's 1986 papers, some prior references omitted by Cock, and references from 1986-1992 listed by the "Current Awareness Literature Service" of the National Agricultural Library, USDA.

In 1993 Butler and Naranjo subsequently prepared two additional bibliographies of *B. tabaci* (unpublished). One contained additional references up to 1993 to supplement the 1992 bibliography and the second contained a listing of the abstracts submitted to the First and Second Annual Reviews of the 5-year plan held in Tempe, Arizona and Orlando, Florida, respectively. These abstracts were published in "Sweetpotato Whitefly: 1993 Supplement to the Five-Year National Research and Action Plan" (ARS 112) and "Silverleaf Whitefly (Formerly Sweetpotato Whitefly, Strain B) 1994 Supplement to the Five-year National Research and Action Plan" (ARS 125). Unfortunately, abstract titles were not provided in ARS 112 and so we provided each abstract with some key words in brackets.

Independently, M. J. W. Cock published an update to his original bibliography "*Bemisia tabaci* - An Update 1986-1992" in 1993. In this current bibliography we have attempted to assemble a comprehensive listing of references on *B. tabaci* including 1) all of our previous bibliographies, 2) the two bibliographies of Cock, and 3) additional references not listed in any prior bibliography. This latter category includes new references since 1993 and the abstracts of two recent international meetings; "The International Workshop on *Bemisia* spp., an Assessment of the Biology and Management of *Bemisia* spp. from an International Perspective" held at Shoresh, Israel, October 3-7, 1994 (abstracts published in Phytoparasitica Vol 22[4]), and "The Fifth Arab Congress of Plant Protection held at Fez, Morocco, November 27-December 2, 1994. Also, because one of the most damaging aspects of *B. tabaci* is its role as a vector of plant viruses, we have attempted to include many of the references dealing with viruses that are vectored by *B. tabaci*. Although *Bemisia* may not specifically be mentioned in the title or abstract of many of these papers we believe that their addition will enhance the utility of our bibliography to those interested in plant diseases. Likewise, we have included references on the honeydew-related issue of stickiness. Again, these references may not specifically mention *Bemisia*, but they are clearly relevant to economic problems associated with *Bemisia*. Finally, during 1993 it was proposed that the B Strain of *B. tabaci* represented a new species and it was subsequently designated as *Bemisia argentifolii* Bellows and Perring. This somewhat controversial species designation has yet to be accepted on a worldwide basis. Thus, it has been, and will continue to be, difficult to determine which species is the subject of citations on various studies from different areas of the world. Recent evidence suggests that *B. argentifolii* is of Old World origin, however, this hypothesis needs further study, as does the ecological interactions of this insect with *B. tabaci*, and its role as a vector of virus induced plant diseases. Thus, we are including both species in the present bibliography but chose not to title this a *Bemisia* Bibliography as we have not included other species in the genus.

The economic importance of the *Bemisia* complex on worldwide agricultural production has yet to be quantified. However, extensive losses occur annually. Several sources indicate crop value loss for the United States exceeding $500 million annually since 1991. Also, recent economic data for the Imperial Valley, California alone indicate direct losses in crop value exceeding $100 million each year in 1991 through 1993. Additionally, employment of farm workers associated with the affected crops was reduced by over 3000 jobs in each year. The devastating impact of the *Bemisia* complex on the economy and well-being of agricultural communities and associated industries throughout the world make this compilation of published literature particularly timely and valuable for researchers, educators, extension personnel, and administrators.

We would like to alert users of this bibliography to several points. First, we have noted throughout our bibliography those references which have been cited in Cock's 1986 and 1993 bibliographies. Cock provided abstracts for many of the papers and because many references may be difficult to obtain we thought researchers might find it useful to check Cock's abstracts before beginning the arduous task of locating original papers. Second, we have not attempted to abbreviate many of the names of non-US publications, and have spelled out some names, especially USA state names, to assist students in other countries. Finally, we have not been able to obtain copies of some of the citations and so could not verify spelling, scientific names, irregular punctuation, and accuracy of the location of the reference. We have tried to standardize as much as possible, but our references may not be exactly as given in the original publications.

This bibliography was produced using Pro-Cite 2.1.1 for DOS (Personal Bibliographic Software, Inc., Ann Arbor, MI). For those that send us a blank diskette and mailer, we would be happy to provide a copy of the database. At your request we can also provide a copy of the bibliography in ASCII text or Word Perfect format.

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Index to Some Reference Numbers in the 1995 *Bemisia* Bibliography

MISCELLANEOUS TERMS

HOST PLANTS

DISEASE TERMS (also see plants)

CONTROL METHODS

WHITEFLY PARASITES AND PREDATORS

Appendix B

Minutes of the Silverleaf Whitefly Technical Working Group Meeting

January 31, 1995
Holiday Inn On The Bay, Porthole Room
San Diego, California
1:00 - 3:00 p.m.

Introductory Remarks:

The meeting was called to order by Dr. Faust. Dr. Faust then thanked the Meeting Coordinators Nick Toscano and Tom Henneberry, their staffs, and the Co-Chairs for their diligence in planning and carrying out the meeting. Dr. Faust handed out a list of the names and addresses of the USDA, Sweetpotato Whitefly Research, Education and Implementation Coordinating Group and the agenda for the SLW Technical Working Group meeting.

Report Of Meeting Attendance:

In attendance this year were a total of 203 registrants plus 10-15 additional participants not registered. Foreign visitors represented were from Belgium (1), Dominican Republic (2), France (3), Honduras (1), Guatemala (1), Israel (4), Italy (1), and Mexico (10).

Final Report/Assignments/Deadlines:

A deadline of February 14, 1995 was set for receipt of all corrected and/or additional abstracts, summaries, and matrix tables from Co-Chairs, including the whitefly bibliography appendix to the progress review report.

Abstracts/summaries are to be sent to:

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311 College Bldg. North
University of California
Riverside, CA 92521
(909) 787-7292 or 3920
E-Mail: LISAARTH@UCRAC1.UCR.EDU

It was noted that although Lisa Arth is working on a MAC computer, she has conversion capabilities. The final document, however, must be submitted to the ARS Publication Branch in DOS, WordPerfect or Word format. Please keep this in mind as you prepare your finalized materials for the progress review report.

Specific Instructions for Submissions

Editors' Comments, Progress Review Organizational Team, Executive Summary, Annual Review Objectives, and the Foreword have been included in the meeting handout but should be reviewed and appropriate changes made, if necessary. Current Status of the SLW Problem, the Overview and Recommendations of each section will be prepared by the section chairs.

Format for Section Summaries: Please follow the format used by Section A last year. Submit these summaries directly to Lisa Arth.

Progress Tables: Program Chairs should review the original 5-year Research and Action Plan (Houston, 1992) to determine progress shortcomings or shifts in priorities. Send statements of progress achieved under each research approach to Dr. Tom J. Henneberry's secretary, Marla Lawrence. Tables will be finalized and provided to Lisa Arth directly by Marla Lawrence.

Minutes of this Meeting: Marilyn Reega will transcribe the minutes and send them to Dr. Faust for review. Dr. Faust will return them to Marilyn Reega for finalization and inclusion in the progress report.

Appendices: The 1995 publication bibliography will be finalized by Steve Naranjo and others at the Western Cotton Research Laboratory, Phoenix, AZ, and will be provided to Lisa Arth in a format suitable for conversion. Dr. Dennis Kopp has agreed to help in any additional distribution of the bibliography, bibliography searches, and format conversions.

Final Publication: ARS publication formatting requirements were provided to Lisa Arth and Tom Henneberry by Dr. Faust.

1996 Progress Review Workshop:

Drs. Tom J. Henneberry and Nick C. Toscano have agreed to continue as Meeting Coordinators for the 1996 Progress Review Workshop. Although the position of Co-Chair is a 2-year assignment, anyone desiring to continue service in the position was encouraged to do so. For the coming year, the following individuals agreed to serve as Co-Chairs:

Section A:	David Byrne and Larry Godfrey
Section B:	Jeff Shapiro and Judy Brown
Section C:	John Palumbo and Phil Stansly
Section D:	Kevin Heinz and Oscar Minkenberg
Section E:	Alvin Simmons and Eric Natwick
Section F:	Dennis Kopp and John Norman

Meeting Site: San Antonio, Texas

Local Coordinator: James Coppedge, USDA, ARS.
Dr. Coppedge will begin contacting hotels and making local arrangements within the next several weeks.
Meeting dates tentatively will be scheduled for the end of January or in early February - the final dates will depend on the availability of a suitable hotel and with consideration for the next SRIEG 58 meeting. It is hoped to plan the Progress Review either immediately preceding or following the SRIEG meeting in order to be able to attract some plant pathology scientists to the SLW progress review meeting in 1996. In terms of attracting plant pathologists as participants in the Research and Action Plan, four options were suggested:

a. implement a new and separate action area section (Section G)

b. insert a special category within several of the original action area sections; i.e., in Sections A, B and E.

c. provide for a special plant virus symposium during the meeting

d. form a focus group comprised of plant pathologists and related disciplines

Dr. Harold Browning offered to contact the representatives of the SRIEG group and report to James Coppedge as to their meeting dates and possible interest in interacting with this group.

Advertising the 1996 SLW annual progress review meeting: Cindy McKenzie will serve as an industry coordinator for the 1996 progress review meeting to be held in San Antonio by contacting and inviting the appropriate industry representatives. Dr. Judy Brown will contact professional societies such as American Phytopathological Society, Agronomy Society and the Entomological Society of America.

Cindy Giorgio will send meeting notices to CAPCA and CA College of Agriculture.

James Coppedge will provide notices to NAICC Newsletter, TX Extension Agents and Vegetable Growers Assn.

A number of suggestions for improving the progress review breakout sessions were offered:

a. Each action area section could select an "expert" or "specialist" to present a 5-minute summary of progress.

b. Moderators should keep interest and interaction by posing a series of "key" questions in terms of progress to session participants.

c. The progress review portion of the meeting should continue to be scheduled as nonconcurrent sessions, as was done this year.

d. An individual from EPA should be invited to address current and upcoming regulations and elaborate on "fast track" registration and other policy items specifically affecting agriculture. Larry Ellsworth and Janet Anderson were names proffered as liaison persons and possible participants.

e. It was agreed that time-tables in future meetings should be adhered to, and that if one session is concluded early, the next session should commence at its appointed time, not earlier.

f. It was agreed that each section's Co-Chairs should submit the names of three speakers to the program coordinator for the Plenary session, who will then finally select one to be invited.

g. Dr. Faust noted that before the 1997 progress review conference, progress toward meeting the entire objectives of the 5-Year Plan should be reviewed in a special meeting. A determination should be made as to what steps may be necessary in order to fully meet the objectives within the original timeframe, or whether a continuance of some period of time is needed and what action should be put in place after the 5-year period, especially in terms of implementation actions.

h. It was suggested that Conference Coordinators provide the 1996 research and action plan Co-Chairs with a "mock-up" program for next year's conference as soon as possible.

Issues for the USDA SPW Research, Education & Implementation Coordinating Group

Questions were raised regarding increasing the interaction between the Research, Education & Implementation (REI) Coordinating Group and the Technical Working Group (especially State researchers). Dr. Faust discussed the make-up of the REI Coordinating Group, noting representation from USDA-ARS, USDA-APHIS, CSREES and the SAES. The REI Coordinating Group meets periodically to discuss issues that have been brought to their attention by university and/or USDA representatives, and serves as the major link to the Department and its support of the 5-Year Research and

Action Plan activities. In addition, members of the Technical Working Group were encouraged to correspond with or call members of the REI Coordinating Group with their concerns or issues of interest during the year. Suggestions for the timely evaluation of new parasites and predators should be provided the REI Coordinating group for action.

Dale Meyerdirk announced that there was a bulletin board system at the National Biocontrol Institute in which there was a component whitefly bulletin board for the use of anyone who may be interested. He provided a handout with additional information and access numbers.

International Activities

Dr. Mayer presented a short report on the International Sweetpotato Whitefly Workshop held in Shoresh, Israel, in October 1994. The meeting was organized by Dan Gerling and Dick Mayer. Dr. Mayer is in the process of organizing an International Working Group. Resolutions will be mailed to the attendees of the first International Sweetpotato Whitefly Workshop. Copies may be obtained from Dr. Mayer. A Second Sweetpotato Whitefly International Workshop is being planned and could be held in conjunction with the 5th Annual Review Conference of the 5-Year Research and Action Plan.

Other Items from the Floor

It was agreed that an organization meeting of the Co-Chairs be held next year, probably the evening before the start of the formal meeting. It was also agreed that Co-Chairs communicate by conference call, FAX, mail, or whatever means necessary to help with planning of the progress review next year. Drs. Henneberry and Toscano will prepare a letter to the Technical Working Group members requesting input on the future role and responsibilities of the working group. It was agreed that the Technical Working Group may need to meet occasionally to discuss current/future issues.

Dr. Stansly provided the Working Group with a definition of the term "Biorational": "Any type of insecticide active against pest populations but relatively innocuous to non-target organisms, and therefore non-disruptive to biological control." This definition was also discussed by Stansly in an abstract titled "The rationality of biorational insecticides for control of silverleaf whitefly (*Bemisia argentifolii*) submitted to Section C for the 1995 Annual Progress Review Conference.

Drs. Toscano/Henneberry reported that no excess funds from registration will be available to carry forward to next year's meeting in San Antonio.

It was stated that the one-page abstracts as a part of the meeting "handout" materials should be continue as standard practice since they serve as an information source, as well as serve to stimulate networking and personal contact among scientists.

A copy of the abstract handout should be provided to the local coordinator for the 1996 Annual Progress Review, Dr. Coppedge. Final copies might be delivered by the printer to the meeting site in order to save mailing costs and handling. If necessary, reimbursement for these costs may be made from registration fees.

Co-Chairs should be provided a FAX or hard copy of all abstracts no later than the deadline established. This will enable Co-Chairs to determine progress made within their sections ahead of time and to better prepare for the progress review sessions.

A copy of the original 5-Year Research and Action Plan Summary Tables should be copied and provided the Co-Chairs for their use in the progress review and evaluation sessions. All Co-Chairs should prepare overheads or slides of their section's tables for use at the meeting so that the audience can more easily follow the discussions.

Dr. Faust adjourned the Technical Working Group Meeting at 3:00 p.m.

Respectfully Submitted,

Marilyn T. Reega, Secretary (retired)
USDA-ARS-Western Cotton Research Laboratory
Phoenix, AZ 85040

Enclosures: Agenda
List of Attendees

Appendix B (continued)

List of Attendees of the Technical Working Group Meeting:

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Appendix C

THIRD ANNUAL PROGRESS REVIEW OF THE 5-YEAR NATIONAL RESEARCH AND ACTION PLAN FOR DEVELOPMENT OF MANAGEMENT AND CONTROL METHODOLOGY FOR SILVERLEAF WHITEFLY

AGENDA

Saturday, January 28 - Travel day

5:00 p.m.	WRCC-87 Meeting - Biology and management of silverleaf whitefly (SLWF), *Bemisia argentifolii* [Location: Porthole]	*Announcements & program by Larry Osborne and Henry Vaux*

Sunday, January 29

7:00 a.m.	REGISTRATION (available throughout the day) [Location: Lobby of Pacific Ballrooms]	

Plenary Session: Invited Presentations
[Location: Pacific Ballrooms A&B]

7:00 a.m.	CONTINENTAL BREAKFAST	
8:00 a.m.	Welcome: Research Progress and Technology Transfer	*Robert M. Faust*
8:20 a.m.	Charge to Conference	*Tom J. Henneberry*
8:30 a.m.	Potential for Using Fungi in Greenhouses	*Lance Osborne, Univ of FL*
8:55 a.m.	Effects of Host Plants on Searching Behavior of Parasites	*Tom S. Bellows Univ of CA, Riverside*
9:20 a.m.	The Recent Introduction of Tomato Yellow Leaf Curl Geminivirus into the Western Hemisphere: Implications for United States Tomato Production	*Robert L. Gilbertson Univ of CA, Davis*
9:45 a.m.	BREAK	
9:55 a.m.	Induction of Tomato Irregular-Ripening by SLWF Feeding	*Cynthia LeVesque Univ of CA, Riverside*
10:20 a.m.	Whitefly Feeding Biology: From Basic Research to Novel Controls	*Allen Cohen, ARS*
10:45 a.m.	Advances in the Development of Sampling Methods and Action and Economic Thresholds for Whitefly Management	*Steve Naranjo, ARS*
11:10 a.m.	Status and Management of Insecticide Resistance in Whiteflies in the Imperial Valley, California	*Nilima Prabhaker Univ of CA, Riverside*
11:35 a.m.	Hypertext Knowledgebase on Whiteflies	*Thomas R. Fasulo Univ of FL*
12:00 noon	LUNCH	

1:30 p.m.	**CONCURRENT MEETINGS** **SECTION A [EAST COAST BALLROOM],** **SECTION C [PORTHOLE], AND** **SECTION E [WEST COAST BALLROOM]** **10-minute presentations of submitted papers--see attached**		
6:30-9:30 p.m.	MIXER AND POSTER SESSION [Location: Pacific Ballrooms B&C]		

Monday, January 30

7:00 a.m.	CONTINENTAL BREAKFAST [Location: Pacific Ballrooms A&B]		
8:00 A.M.	**CONCURRENT MEETINGS** **SECTIONS B [EAST COAST BALLROOM],** **SECTION D [PORTHOLE], AND** **SECTION F [WEST COAST BALLROOM]** **10-minute presentations of submitted papers--see attached**		
11:30 a.m.	LUNCH **Program and Progress Review** [Location: Pacific Ballrooms A&B]		
1:00 p.m.	Section A: Ecology, Population Dynamics and Dispersal	*Co-Chairs:*	*Marshall Johnson, Univ of HI* *Larry Godfrey, Univ of CA*
2:15 p.m.	Section B: Fundamental Research--Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions	*Co-Chairs:*	*Jeff Shapiro, ARS* *Judith K. Brown, Univ of AZ*
3:30 p.m.	BREAK		
3:45 p.m.	Section C: Chemical Control, Biorationals, and Pesticide Application Technology	*Co-Chairs:*	*John Palumbo, Univ of AZ* *Phil Stansly, Univ of FL*
5:00 p.m.	Meeting with Agricultural Chemical Industry Representatives [Location: Pacific Ballrooms A&B]		

Tuesday, January 31

Program and Progress Review
[Location: Pacific Ballrooms A&B]

7:00 a.m.	CONTINENTAL BREAKFAST		
8:00 a.m.	Section D: Biological Control	*Co-Chairs:*	*Oscar Minkenberg, Univ of AZ* *Kevin Heinz, Univ of CA*
9:15 a.m.	Section E: Crop Management Systems and Host Plant Resistance	*Co-Chairs:*	*Eric Natwick, Univ of CA* *Alvin Simmons, ARS*
10:30 a.m.	BREAK		
10:45 a.m.	Section F: Integrated Techniques, Approaches, and Philosophies	*Co-Chairs:*	*Donald A. Nordlund, ARS* *Dennis Kopp, USDA-ES*
12:00 noon	Closing Remarks		*Tom J. Henneberry* *Nick C. Toscano*

1:00 p.m.	SLWF Technical Working Group Meeting [Location: Porthole]		*Robert M. Faust, moderator*

CONCURRENT GROUPS A, C AND E:

SECTION A: ECOLOGY, POPULATION DYNAMICS AND DISPERSAL [LOCATION: EAST COAST BALLROOM]

1:30 p.m.	WELCOME AND INTRODUCTIONS	*Co-Chairs:*	*Marshall Johnson, Univ of HI* *Larry Godfrey, Univ of CA*
	Counting whiteflies		*Joe Ellington*
	Vertical distribution of the whitefly in two varieties fig, Mexicali, B.C.		*Pedro Mendez Paramo*
	Seasonal Sex Ratio Dynamics of Whiteflies in Imperial Valley, California		*Steven Castle*
	Seasonal Development of SLWF Populations on Crops in the San Joaquin Valley		*Larry D. Godfrey*
	Continuous honeydew production by SLWF nymphs on cotton		*W. L. Yee, D. L. Hendrix, N. C. Toscano, C. C. Chu, T. J. Henneberry*

SECTION C: CHEMICAL CONTROL, BIORATIONALS AND PESTICIDE APPLICATION TECHNOLOGY [LOCATION: PORTHOLE]

1:30 p.m.	WELCOME AND INTRODUCTIONS	*Co-Chairs:*	*John C. Palumbo, Univ of AZ* *Phil Stansly, Univ of FL*
	Silverleaf Whitefly: Progress in Developing Adult Chemical Control Action Thresholds		*T. J. Henneberry, N. C. Toscano, C. C. Chu, R. L. Nichols, T. F. Watson, P. Ellsworth, S. Naranjo, D. G. Riley*
	Periodo critico y umbrales para el control quimico de *Bemisia argentifolii* en algodonero		*Marcelo Machain Lillingston*
	Monitoring for resistance to insecticides in whitefly populations from the Yaqui Valley, Sonora, Mexico		*Jose Luis Martinez Carrillo*
	Susceptability tests for some common insecticides in *Bemisia tabaci* (*Gennadius*) collected from cabbage in La Paz, Mexico		*Rosalia Servin, J. L. Martinez Carrillo, E. Troyo, A. Ortega*
	Selection With Acephate, Amitraz, Imidacloprid, Fenpropathrin, Phenoxycarb and Methamidophos of *Bemisia argentifolii* B Strain in Greenhouse		*Dan A. Wolfenbarger, D. G. Riley, Weijai Tan*
	Status of Imidacloprid as a Management Tool for SLWF on Vegetables and Cotton		*Walt Mullins*
	Activity of Surfactants and Oils Against SLWF and *Encarsia pergandiella*		*Philip Stansly, T. X. Liu*

	Ground Application with Medium Pressure Sprays of 400 PSI for control of SLWF in IPM Programs in Cotton		*D. H. Akey, T. J. Henneberry, C. C. Chu*
	SLWF Control in Cotton with Pyriproxyfen, an IGR		*Mike Ansolabehere*
	Evaluacion de mezclas de insecticidas para el control quimico de mosca blanca, *Bemisia argentifolii*, en el cultivo del algodonero		*Ricardo Reyes Catalan*
	Garlic Oil for Whitefly Control on Cotton		*Hollis M. Flint*
	Control of whitefly with ovasynt phaser		*Philip Odom, John Lublinkopf, Fred Strachan*

SECTION E: CROP MANAGEMENT SYSTEMS AND HOST PLANT RESISTANCE [LOCATION: WEST COAST BALLROOM]

1:30 p.m.	WELCOME AND INTRODUCTIONS	*Co-Chairs:*	*Eric Natwick, Univ of CA* *Alvin Simmons, ARS*
	Physical Means for the Control of *Bemisia tabaci*		*Menachim J. Berlinger*
	Response of broccoli cultivars to *Bemisia argentifolii*		*Jorge Sosa-Coronel*
	Tolerance varieties of cotton of whitefly, *Bemisia argentifolii*, Mexicali, B.C. 1994		*M. C. Ruben Martinez*
	Evaluation of Lettuce for Resistance to SLWF		*James D. McCreight*

CONCURRENT GROUPS B, D AND E:

SECTION B: FUNDAMENTAL RESEARCH--BEHAVIOR, BIOCHEMISTRY, BIOTYPES, MORPHOLOGY, PHYSIOLOGY, SYSTEMATICS, VIRUS DISEASES, AND VIRUS VECTOR INTERACTIONS [LOCATION: EAST COAST BALLROOM]

8:00 a.m.	WELCOME AND INTRODUCTIONS	*Co-Chairs:*	*Jeff Shapiro, ARS* *Judith K. Brown, Univ of AZ*
	Relatives of *Bemisia*, a complex taxonomic unit		*Raymond J. Gill*
	Morphological & Molecular Studies on the Systematics and Evolution of Whiteflies		*Bruce Campbell, Jody Steffen-Campbell*
	Genetic variation in geographic samples of *Bemisia*		*Alan C. Bartlett*
	Characterization of sex-specific gene expression in silverleaf and sweetpotato whiteflies by differential RNA display		*Cynthia S. Levesque, Thomas M. Perring, Linda L. Walling*
	White Feeding Biology		*Allen C. Cohen*
	Dissecting the Role of Terpenoids in Glandular Trichome-Based Insect Resistance		*Sheila M. Colby*
	Geminivirus Interactions with *Bemisia* Organ Systems		*Kerry F. Harris*

	Relationship between SLWF populations and sticky cotton	*C. C. Chu, T. J. Henneberry, H. H. Perkins*
	Studies on parasites of *Bemisia*	*M. Rose, J. B. Woolley, M. Shauff, G. Folnerowich, J. Heraty*
	Tritrophic relationships involving *Bemisia* and *Delphastus pussilus*	*Dan Gerling*

SECTION D: BIOLOGICAL CONTROL [LOCATION: PORTHOLE]

8:00 a.m.	WELCOME AND INTRODUCTIONS *Co-Chairs:*	*Oscar Minkenberg, Univ of AZ* *Kevin Heinz, Univ of CA*
	Foreign exploration and evaluation of some natural enemies of *Bemisia argentifolii* from Southeast Asia	*Susie C. Legaspi*
	Drought adapted natural enemies of SLWF in Thailand	*A. A. Kirk, L. A. Lacey, J. Goolsby, M. E. Schauff*
	Biological control of SLWF on eggplant in Hawaii	*Marshall W. Johnson, Lynne Kaneshiro, Diane E. Ullman*
	Evaluation of two strains of *Encarsia formosa* Gahan parasitizing *Bemisia argentifolii* on hibiscus: Bionomics in relation to temperature	*Michael T. Smith*
	Reproductive biology and behavior of an *Eretmocerus* sp. from Texas	*Walker A. Jones*
	Evaluations of field releases of *Eretmocerus californicus* in San Joaquin Valley, California, cotton	*Kevin M. Heinz, James R. Brazzle, Charles Pickett*
	Searching behavior of *Eretmocerus* sp. on glabrous and hirsute melon varieties	*Ned M. Gruenhagen, Thomas M. Perring*
	What *Eretmocerus* can--and cannot	*Oscar Minkenberg*
	Introduction of exotic parasitoids into desert agroecosystems	*K. A. Hoelmer*
	Natural Enemy Refugia	*William Roltsch*
	Effect of host plant on activity of *Paecilomyces fumosoroseus* against *Bemisia tabaci*	*L. A. Lacey, A. Vey, A. Kirk*
	Assessment of *Paecilomyces* and *Beauveria* Against SLWF in Imperial Valley, California	*Stefan T. Jaronski*
	Efficacy of fungal pathogens against SLWF on cucurbits in southern Texas	*S. Wraight, R. Carruthers, S. Jaronski, C. Bradley, S. Galaini-Wraight, N. Underwood, J. Britton, J. Garza*

SECTION F. INTEGRATED TECHNIQUES, APPROACHES, AND PHILOSOPHIES [LOCATION: WEST COAST BALLROOM]

8:00 a.m.	WELCOME AND INTRODUCTIONS	*Co-Chairs:*	*Donald A. Nordlund, ARS* *Dennis Kopp, USDA-ES*
	Establishment of IPM Infrastructure: A Community-Based Action Program of Sweetpotato Whitefly (SPWF) Management		*Peter Ellsworth, J. W. Diehl, S. H. Husman*
	An Integrated Approach to SPWF Management in the Lower Rio Grande Valley of Texas		*John W. Norman Jr., Alton N. Sparks Jr., David G. Riley*
	Getting the Message Out--Training and Developing Extendors of Whitefly Knowledge		*Peter B. Goodell*
	The World of the Whitefly Seen From Space		*J. C. Allen, C. C. Brewster*
	SLWF Management on Cotton in the Mexicali Valley, 1994		*Raúl León-López*
	IPM and Whitefly Control from the Growers' Perspective		*Eric T. Natwick*

Appendix D

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Appendix E

Current Protocols for Ground Application of Chemical Trials Against the Silverleaf Whitefly (SLWF) for the 1995 Growing Seasons (aka Sweetpotato Whitefly, Strain B)[(a), (b)]

Based on information derived from the January, 1995
SLWF Review Workshop at San Diego, CA
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The severity of whiteflies (WF) damage to crops across the Southern US required immediate measures to be instituted to reduce the damage. For this action, protocols for ground applications were established in a cooperative effort at the WF Workshop for Applications of Chemicals Against WF at San Antonio, TX, January 23-24, 1992, to obtain uniform tests that would generate data useful for comparisons of WF chemical trials in the 1992 growing seasons on several crops at a number of locations. Some chemical agents were compared nationwide; others were restricted to comparisons specific to locations because of various requirements or conditions. The 1992 protocols were used for the 1993 growing seasons also. In 1994, after two years of experience and hindsight, the protocols were revised. These 1994 protocols were reviewed by members of section C at the 1995 SLWF workshop for use in the 1995 growing seasons. The following protocols reflect changes and simplifications suggested by those members.

Sampling units that must be reported are set in bold type. The latter are a minimum. Investigators are encouraged to report as much detail as possible regarding methods, materials, meteorological conditions during the test periods, and particularly, leaf area of leaves sampled and some indication of the homogeneity of the SLWF distribution. It may be necessary to record this information as appendices, but it is important to acquire the data.

Retain raw data and summaries in addition to analyzed data and reports for regulatory agencies; e.g., EPA. Raw data and summaries are used by regulatory agencies for statistical analysis for making determinations about the efficacy and usefulness of the compounds tested for section 18's and other regulatory categories.

Again, the objectives of the protocols that follow are to insure enough uniformity between trials to make some valid comparisons and draw useful conclusions about compounds, crops, and application methodologies as regards SLWF. The following protocols include, but are not limited to, the crops listed below:

Cotton and ornamentals; e.g., poinsettias.
Peanuts; roses
Vegetables

Tomatoes
Eggplant
Melons/cucurbits

Cole crops
Leafy greens.

Each researcher should communicate with the company product manager and /or the technical representative to request the amount of material needed for tests. Researchers should check with the contact person to establish reasonable lead times for requests of materials to assure timely deliveries without "crisis" deadlines.

Protocol I: Standardized sampling counts of SLWF. **Take samples at least weekly. Distinguish SLWF immatures and adults from banded-wing whitefly (BWWF) or other species in your area for accurate data collection. Other species sometimes occur during specific parts of a season. Keep voucher specimens suitable for biochemical differentiation of SPWF verses SLWF.**

A. **For eggs and immatures, take counts from undersides of leaves.**

1. Counting methods: the method chosen is the investigators choice. However, one method must be used consistently during the whole season to aid statistical analysis; e.g., early in the

(a) Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.

(b) Protocols established by the SPWF workshop at San Antonio, TX, January 23-24, 1992; revised at SPW workshop at Houston, TX, February 1992, and March 12 and 23, 1992.

population I increase, it may be easy to do whole leaf counts, but later it may be only practical to do a leaf-disk count/leaf; nevertheless, still make leaf-disk counts early in the season along with the whole leaf counts. This way there will be one counting method to generate data for the entire season analysis; and, at the discretion of the investigator, earlier season data may be analyzed by a more sensitive method; e.g., whole leaf counts. **If whole or partial leaf counts are used, then the leaf area for each count must be determined so that the number per unit area can be reported.**

a. disks; most investigators now use one disk from each leaf sampled. Usually, the disk is being taken from the base of the leaf and centered on the main vein. Disk sizes have varied; e.g., diam. 1.13" = 1 sq inch = 6.45 cm sq; diam. 1.0" = 0.78 sq inch = 5.03 cm sq. Past sampling schemes have used 2 disks–one from each leaf half, or four 10-mm diam. disks/leaf, one from each leaf quadrant; but taken near the base of the leaf (3.1416 sq cm).

b. grids may be superimposed over leaf disks or leaves and counts made. Grids increases accuracy when counting leaf disks with areas greater than the field of the microscope.

c. whole, half, or partial leaf; **determine area**

2. Eggs will be reported as **eggs/cm^2**, usually from a fully expanded top leaf.

3. Report immatures as **large nymphs/cm^2**. Use a fully expanded upper leaf that usually has the most large nymphs present; e.g., in cotton, leaf 5 is typical, as counted from the top, off the main stem. Alternatively, based on review of these protocols by a bio-statistician, leaf sampling for immatures that are based on selection of the leaf with the most large immatures will produce more consistent samples with a lower variance than arbitrary selection of a particular leaf as numbered from the top or bottom of the plant. This biases the count toward a high estimate but helps determine efficacy in the "worst-case scenario."

a. Same sampling and counting schemes as for egg.

b. **Large nymphs will include large 3rd's, small 4th's, and red-eye nymphs (pupae).**

4. Leaf packaging and storage: It is convenient to seal leaves from individual plots in "zip lock" type plastic bags and record the plot and date data, etc., right on the bag with a permanent marker. Keep collections very cool from the time of collection in the field and throughout storage in the lab. Leaves should be examined as quickly as possible via a stereo-microscope. This is a time-consuming process--be ready! Bags of leaves need to be examined for mold often, in order to set priorities for counting order. I have been unsuccessful in attempting to count dried leaves but Dr. Dan Gerling reports successful immature counts from previously frozen material.

B. For adults: experience from several locations across the country has shown that it is difficult to measure treatment effects on adults in small plot trials. Separation of treatment means are usually not statistically significant due to the movement of adults in and out of the plots. Also, methods to determine adult numbers during a regime of treatments are not necessarily the same as methods relevant to determine action thresholds to begin trials. If resources are very limited, you may make a decision not to sample adults. Adult counting methods include: the "leaf-turn" technique, sticky card, sticky pan (see AZ work of G. Butler, L. Antilla), and vacuum sampling (see CA work of CDFA, San Joaquin Valley); only the first 2 methods will be discussed here.

1. **Leaf-turn method: counts should be reported per whole leaf.** This makes comparisons between crops difficult as attempts to report this per unit area of leaf have been unsuccessful. Currently, it is the only method accepted by PCA's and Consultants because of it ease of use and rapidity.

a. **sample 24 or 48-hr post treatment.**

b. sample in early morning if possible.

c. be careful not to disturb whiteflies in crop while sampling.

d. leaves to be sampled are left to discretion of investigator. In cotton, one scheme has been to take an average of the sum of 3 leaves, one leaf each from the bottom, middle, and top of canopy (see Sampling Sweetpotato Whiteflies in Cotton, P. Ellsworth, et al., UA Coop. Ext. IPM Series No. 2, 1994).

2. Yellow sticky cards: counts will be reported as **SPWF adults/cm^2**.

a. Use plot size of a minimum of 1.0 acres and 24-hr sample time in 48-hr window.

b. Card oriented perpendicular to row in a vertical position with plant.

c. Card positioned somewhere between middle to lower third of plant; for low plants such as lettuce and cucurbit vines, place cards as needed close to top of plants and use cards appropriately smaller in size if needed.

d. Card counted on both sides, area counted to be same throughout season.

e. Chose "own appropriate size" card and amount of area of the card to count.

f. Source of yellow sticky cards (**both sides sticky**) and methods of preparation:

(1) Olson Products
P.O. Box 1043
Medina, Ohio 44258
(216) 723-3210

3" X 5";	box of 100 cards	$ 29.95
	case of 10 boxes (total of 1000 cards)	$229.95
6" X 12";	box of 50 cards	$ 57.95
	box of 400 cards	$369.95
	case of 4 boxes, 125/box, 500 total	$410.95
12" wire stakes to hold cards (can be secured to wood poles)		
	box of 100 stakes	$ 26.95
	3 boxes of 100 stakes, price per box	$ 24.60
	10 boxes of 100 stakes, price per box	$ 21.00

(2) Order cards most appropriate in size to use "as is" or to cut to size needed. It may be possible to custom order cards cut to specific sizes.

(3) There are sources of cards that are preprinted with a grid but I am unaware of where to obtain such cards that are sticky on both sides.

(4) Bring a roll of plastic cling wrap to the field and cover cards with it. Always mark card orientation by a mark or notch and have a method for identifying the plot, date, site, etc. The ID can be as simple as ink via a felt pen over the cling wrap (in an area not to be counted) or a tiny preprinted label.

(5) Cards with SPWF are easily kept in a freezer until counted.

(6) Grids for counting can be easily scored with a felt-tipped pen right over the cling-wrap, i.e., the wrap does not need to be removed.

Protocol II: Standardized sampling, replicates, and treatments.

A. **For eggs and immatures: minimum of 4 replicates for plots $\leq$0.01 ac /treatment or 3 replicates for plots $\geq$0.1ac , and 5 leaves/replicates (remember that a test with more replicates will give better statistical separation due in part to the increased degrees of freedom in the statistical analysis of the data.**

B. **Adults: minimum of 5 leaf-turn samples or 1 yellow sticky card/replicate (plot).**

Protocol III: Ground Applications [c].

A. Experimental design:

1. Type: this is left to the discretion of the investigators but consideration should at least be given to the pros and cons of various designs; e.g., a, b, and c below; latter is recommended by author.

a. Random block design with tiers of replicates with treatment position within tiers chosen at random. This design embeds check plots throughout the design and tends to negate effects of non-study parameters, but allows possibility of treatments to influence check plots by changing the populations around them therefore imparting the undesirable attribute of being dependent variables.

b. Latin square. This places treatments and check plots uniformly throughout the design and is strong in reducing non-study parameter effects; check replicates may also be influenced by surrounding treatment replicates as in (a). It requires that treatment numbers equal replicate numbers. However, it has the same disadvantage as the random block design as check plots may become dependent variables.

[c] See separate protocols for aerial application, pp 105-125 in 1992 Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly, Houston TX 1992, ARS-107.

c. Random block or Latin square design (check plots embedded in the design) but with a separate check block of untreated plots. The check block should have dispersed sampling points equal in number to the number of replicates/treatment in the accompanying random block or Latin square design. This allows the treatments to be compared to both embedded checks and the check block samples. It also allows the investigator to determine something about the independence (or dependence) of the embedded checks. This design has received a favorable review from a bio-statistician.

2. Regardless of the test design chosen, the investigators must consider the benefits of isolation of plots (replicates) or blocks to reduce the influence of SLWF movement between them. For example, in the row crop cotton, lower variance in data was observed in plots isolated by 3-fallow-row corridors and 20-ft alleys than by 2-row-corridors and 3-ft alleys (authors data).

3. The plot size and number of rows have been left to the discretion of the researchers because of the great differences in crop phenologies, morphologies, and systems.

4. Action thresholds for initiation of applications are to be determined by the investigators but must be reported. The purpose of the action threshold must be considered. Is it to protect plant growth itself, prevent stickiness, or stop viral or toxin transmission? Also the degree of SLWF infestations in nearby crops and around the trial field may determine the action threshold level chosen. Perhaps most importantly, even if the SLWF population is low, has it doubled within 7-10 days? The latter is almost a sure indication for action (author opinion). For cotton, see work of Ellsworth and Naranjo; for melons, see work of Palumbo.

B. **Application methods:**

1. **List all parameters including:**

   a. **Crop information; e.g., size, stage, fruit, season.**

   b. **Nozzles & types/row.**

   c. **Application equipment and details.**

   d. **Tank pressure in PSI (and if possible delivery PSI).**

   e. **Weather - at time of application.**

   f. **Calibration.**

   g. **Use only one method of application.**

2. **Applications are to be applied by motorized ground equipment, back pack sprayers are not to be used (even if operated by pressurized gas tanks or motorized).**

3. Determine particle deposition to report percent coverage, droplet size in mg., and total deposition in $\mu g/cm^2$. This must be done at least once in each trial, usually at the time of densest canopy or foliage. Dye applications followed by determination of area covered, leaf washes of single leaf side, use of water sensitive papers, and microscopic examination are useful techniques to obtain these data.

4. Action thresholds for initiation of applications are to be determined by the investigators but must be reported. The purpose of the action threshold must be considered. Is it to protect plant growth itself, prevent stickiness, or stop viral or toxin transmission? Also the degree of SPWF infestations in nearby crops and around the trial field may determine the action threshold level chosen. Perhaps most importantly, even if the SPWF population is low, has it doubled within 7-10 days? The latter is almost a sure indication for action (author opinion).

C. Chemicals:

1. **Follow rates suggested by company representative and report each as ai/ac.**

2. pH and alkalinity of application (mix) water:

   a. sample water and have it tested before applications start, if the source changes, once during the season, or any time that there is cause to question if the water quality has changed significantly.

   b. Collecting of application water for pH and alkalinity testing: container and volume: collect 1 pt. (475 ml) of water in a water

tight, thoroughly-rinsed plastic bottle. Let the water run for two minutes before collecting the sample. Fill the container to the very top leaving as little air space as possible so CO_2 in the air does not mix with the water's components and raise its alkalinity. Keep samples cool.

c. If buffering is required for pH adjustment for pH sensitive agents, then consult with company contacts for that agent.

3. **Each agent must be tested in the field at least once with one treatment (season long) without an adjuvant. If an adjuvant is used in a second treatment or in following seasons, then an additional treatment must be conducted with the adjuvant alone.**

4. **Investigators are to individually test agents for inclusion in these tests with the exceptions of specific company requests that the agent be tested with a second agent. If so follow a procedure similar to 3) above.**

D. **Application frequency:**

1. **Ideally, 10 applications are desirable; may be crop dependent.**

2. **Applications should be made every 7 days if possible but no longer than 14 days should pass between applications (exception is imidacloprid applied as a systemic, then crop should be closely monitored to determine when to initiate foliar sprays).**

3. The number of applications may require that a lower rate be used for each application. Do not go below an effective rate for any one application. If the total application amount for the season exceeds the maximum allowed, the treated crop must be destroyed after the end of the experiment as a research trial and must not exceed parameters (e.g., 10 ac in size) that would qualify it as needing an experimental use permit (EUP).

E. **Crop Parameters:**

1. **Yield (in units used for each specific crop).**

2. **Phytotoxicity, if present; may require rate reduction on sensitive crops.**

3. **Alteration of plant phenology/ morphology, or any other growth differences from the check.**

(d) Contact Dr. I. (Buddy) Kirk, USDA, ARS, SPA, Areawide Pest Management, College Station, TX for technical information.

Appendix F

Proposed Chemical Control Study for 1995 to Aid IPM Programs

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C. Chemical Control, Biorational, and Pesticide Application Technology:
Large scale study to partially meet research approaches C.3 and C.4 for years four and five.

Optimal Insecticide Use for Whitefly: Aerial Versus Ground, Thresholds, and Resistance Strategies

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J.B. Carlton[3], J.R. Coppedge[3], and T.J. Henneberry[2]

University of Arizona, Maricopa, AZ[1],
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This proposed study will provide critical information regarding selection and use of insecticides for controlling whitefly in cotton. Fundamental gaps exist in our knowledge of how to obtain the needed control of the silverleaf whitefly while limiting chemical use to the lowest practical levels. In this 12 factorial experiment with 3 replicates of 5-ac plots on 180 acres at the University of Arizona, Maricopa Agricultural Center, we will evaluate and contrast interactions between:

(a) ground vs. air applications,
(b) 3 action thresholds for initiating treatments against whitefly, and
(c) 2 rotation schemes of insecticides for thwarting resistance development.

The large scale of the experiment, coupled with the high level of interest by researchers and growers in the questions being addressed, insure that this study, if successfully completed, will generate information of utmost importance to both groups.

TABLE A. Ecology, Population Dynamics, and Dispersal[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Systematic study of SPW on cultivated and weed hosts, seasonal time of occurrence, habitat.	Identify preferred hosts, determine seasonal distribution, determine developmental, reproductive and mortality rates of SPW on crop and weed hosts.	Continue demographic studies, determine relationships between crop sequencing, preferred hosts and population dynamics.	Determine seasonal contribution of cultivated and wild host plants to SPW population dynamics.	Describe role of cultivated and wild host plants on the population dynamics of SPW, identify weak links in seasonal biology.
A.2 Develop efficient SPW sampling plans for research and decision making purposes	Determine spatial distributions, define sample units for immature and adult SPW, examine variance components, optimize sample number and allocation.	Formulate sampling plans, determine relationship between sampling techniques for adults and crop infestations, evaluate feasibility of a standard sampling technique.	Continue development and refinement of sampling plan, implement and test protocols, develop remote sensing tools to estimate regional population levels.	Continue testing and implementation of sampling plans in terms of reliability and efficiency, continue development of remote sensing tools.	Finalize sampling protocols.
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Determine components of yield and quality affected by SPW feeding, virus transmission and honeydew production on crop studied.	Determine and quantify relationships between SPW population density and plant yield and quality, formulate economic thresholds in relation to sampling protocols.	Continue quantification of relationships between SPW density and yields and quality, continue formulation of economic thresholds with refined sampling protocols.	Perform economic analyses, evaluate economic thresholds in crops studied.	Continue economic analyses.
A.4 Develop and test population models to describe and predict SPW dynamics.	Determine model goals, define preliminary model structures and identify data needs, evaluate existing biological information.	Develop relationships between SPW biology and crop phenology and crop sequencing. Integrate SPW, natural enemy, and plant components into simulation models.	Continue model construction, evaluate data needs, begin evaluation of model predictions of SPW population development.	Validate simulation models under field conditions, analyze model behavior.	Identify existing information gaps in insect and plant interactions.
A.5 Determine factors influencing SPW dispersal.	Determine relationships between crop phenology, crop status and SPW dispersal.	Determine biological factors (physiology, behavior, sex, etc.) influencing dispersal.	Determine effects of weather parameters on dispersal.	Examine interrelationships of crop production methods and SPW dispersal.	Summarize information on research progress on SPW dispersal and propose needed research.

A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Develop marking methods (immunological, rubidium, genetical), determine population development and phenology on various crops.	Conduct mark-release studies-recapture studies, quantify seasonal inter-crop and weed movement, determine influence of host sequencing and spatial patterning on SPW population development.	Continue quantification of SPW movement and determination of host sequencing and spatial patterning, integrate information into population models.	Continue as in Year 3.	Exploit potential of information developed on managing SPW dispersal as a control methodology.

1 Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE B. **Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions**[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
B.1 Studies of feeding behavior: sensory receptors, ultrastructure, morphology, digestive physiology; intra- and interspecific competition.	Begin studies of ultrastructure, morphology; analyze feeding and digestive processes; begin studies of parameters influencing competition.	Continue studies from Year 1; characterize feeding by-products and digestive enzymes; determine influence of host plant morphology, physiology, ecology and phenology on SPW feeding behavior and competition.	Continue in-depth studies begun earlier; investigate relationship between endosymbionts and nutrition; use feeding monitor to screen for host resistance and response to residues of pesticides and natural products.	Continue research begun earlier; identify weak links for management-based research.	Continue basic research; investigate approaches for interrupting feeding and digestion, and reducing competitive abilities.
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction, genetics and genetic diversity.	Identify temperature tolerances; begin study of host influences (i.e., water balance, osmotic concentrations, nutrients) on SPW; begin studies of nutritional physiology, reproductive physiology, ploidy level.	Continue fundamental studies begun in Year 1; expand studies of genetic diversity; identify areas for continued emphasis.	Continue basic studies; identify potential weak links for further research: i.e., genetic and physiological bases for host selection, habituation, switching, etc.	Continue basic studies; investigate approaches for interrupting or altering key biological processes.	Continue basic studies; implement strategies for interfering with key processes; assess potential for further development.
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species.	Collect SPW taxa and characterize their validity using morphological, molecular, biochemical, and biological studies to distinguish genetically different populations; develop voucher protocol for preservation of morphological and molecular information; establish centralized molecular services.	Continue systematic analysis of SPW; provide molecular services based on information derived from Year 1.	Continue systematic analysis of SPW; develop rapid identification systems.	Finish analysis of SPW character development of rapid identification system.	Provide synthesis of diagnostic analysis of SPW taxa; relate results to other fundamental approaches; continue molecular identification services; finish development of rapid identification system.
B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Begin analysis of all species of *Bemisia* using at least morphological and DNA sequence analyses; develop collecting and preservation protocols; identify sources worldwide and begin collecting material for analysis.	Continue analyses of *Bemisia* species, defining characters using characters from morphological and DNA sequence studies; investigate value of supplementary methods (i.e., cuticular hydrocarbons, immunological assays, isozymes, symbiont associations, etc.)	Continue analyses of *Bemisia* species, define taxa and begin phylogenetic analysis.	Complete systematic analysis of *Bemisia* species; complete phylogenetic analysis of at least morphological and DNA sequence information.	Complete systematic analyses; validate supplementary methodologies.

B.5 Identify and define SPW toxicogenic effects. Develop dsRNA and cDNA probe.	Characterize toxicogenic effects, cytology and EM.	Fractionate SPW and affected plants. Isolate toxicogenic fractions. Characterize endogenous mediators, Use cDNA probe to screen biotypes.	Define affected plant target molecules and molecules mediating systemic response. Use probe to localize source of dsRNA.	Characterize toxico-genetic molecules and mode of action. Utilize probes for field IDs.	Define mechanisms of plant resistance and integrate knowledge in developing IPM.
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Treat SPW with anti-biotics and determine effects on growth, develop-ment and reproduction.	Develop methods for isolation and SPWe and extraction of nucleic acid. Amplify specific SPWe genes via PCR.	Analyze variability of SPWe genome in different SPW biotypes via RFLP, PFE and hybridization with SPW dsRNA probe	Determine specific genes and gene products associated with SPW metabolism.	Analyze progress and determine feasibility of pest management based on interruption of endosymbiotic relation.
B.7 Investigate etiology of diseases; biological and molecular charac-terization of causal agents; develop under-standing of relationship; molecular probes for viral diseases; diagnos-tics and resistance; virus-vector specificity and interactions.	Collect and establish pure cultures; initiate transmis-sion studies and biologi-cal characterizations, cloning and purification for these studies and antibody production, screening for resistance.	Continue with biological and molecular studies; continue cloning and characterization; begin antibody production. Develop detection and identification systems. Study virus-vector interactions: receptors, transmission, transforma-tion, resistance.	Continue developing virus diagnostics; molecular comparisons of sequence data, relations; continue cloning and characterization; continue virus-vector studies. Develop diagnostic tests for epidemiological purposes; clones for (injured) resistance.	Develop strategies for engineered resistance; prototype isolates based upon molecular charac-terization and distribu-tion studies; biological, molecular parameters, viral designations standard-ized; methods for identification; mechanisms of vector transmission.	Continue virus-vector studies; evaluate resis-tance studies: engineered and classified w/prototype isolates. Continue bio-logical and molecular studies of new pathogens; viral taxonomy; standard-ize names.
B.8 Study epidemiologi-cal parameters: vector population dynamics; disease thresholds; identify sources of inoculum, distribution, severity, and prevalence of pathogens. Correlate efficiency of transmis-sion with biotypes, diversity and parameters of cropping systems.	Initiate study of trans-mission efficiency, vector population dynamics, fecundity studies, host reservoir studies. Survey problem areas to identify key virus isolates; develop transmission thresholds for viruses.	Continue to investigate epidemiological parameters; begin to establish diagnostics; identify key isolates for in-depth characterization; study vector-host plant interactions.	Continue epidemiology studies; evaluate strategic management methods (i.e., sanitation programs based on inoculum sources); study vector-host-virus interactions in field; apply diagnostics.	Continue application of diagnostics to field epidemiology studies. Evaluate distribution, reservoirs using diagnostics; evaluate resistance in field studies.	Continue development, application of management strategies based on epidemiology studies. Transfer information for use in cropping systems, host free periods, recommenda-tions for long term disease management.
B.9 Study mating and oviposition behavior.	Study mating behavior in detail; determine possible role of sex pheromone; study role of mating in oviposition.	Determine factors, environmental and bio-logical, that affect mating; determine factors affecting oviposition site selection and fecundity.	Develop methods for determining mating success, sperm transfer, fertilization, etc.; deter-mine role of nutrition in oviposition and viability.	Identify factors that may be manipulated to manage or present mating; examine potential of attracticides and manipu-lation of crop production in reducing oviposition.	Exploit such factors in field trials to determine their potential in control methodology; quantify role of oviposition behavior in population dynamics.

B.10 Determine factors influencing host plant selection and host acceptance.	Determine nature of physical, environmental, plant host, physiological cues involved; investigate extent of semiochemical mediation in host finding.	Isolate, identify chemicals and other cues involved; continue studies of host selection and acceptance.	Develop bioassay methodology for quantifying semiochemical effects on SPW behavior.	Determine interactions of semiochemicals with environmental factors, incl. natural enemies.	Determine potential for manipulating semiochemicals and other host-finding or acceptance cues as behavioral components in SPW control systems.
B.11 Identify plant nutritional and defensive responses to SPW and their effects on SPW and natural enemies.	Identify proteins, enzymes, and natural products induced in plants by SPW; examine influence of changes in nutrient levels on SPW and enemies.	Isolate and characterize induced protein, enzymes, or compounds.	Determine effects on SPW and evaluate as resistance mechanism; evaluate effects on SPW natural enemies.	Identify source of defensive factors in plants and their targets in SPW; continue studies of tritophic level interactions.	Target specific factors for genetic engineering of plant resistance.

1 Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE C. Chemical Control, Biorationals and Pesticide Application Technology.[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
C.1 Identify, for registration, new chemicals and formulations that effectively control SPW.	Lab and field evaluation of chemicals with rates, combinations to identify promising materials.	Expand field research with best combinations and application methodology.	Evaluate new chemicals in relation to stage of insect killed, economic threshold, and effect on beneficials.	Determine chemical effects of SPW populations, increased yields, and quality of crops to provide data useful for registration purposes.	Formulate control strategy based on research progress that indicates rates, gal/ acre, frequency of applica-tion, and associated secondary pests.
C.2 Identify, for registration, biorational materials with new modes of action.	Initiate studies with oils, soaps, natural products, both organic and inorganic, to determine efficacy.	Conduct field studies to determine coverage, rates, gal/acre, etc., to provide data useful for registration purposes.	Expand studies with best materials with highest potential. Evaluate efficacy, timing, alternatives with other chemicals.	Develop alternating sequences between chemicals and biorationals for best SPW management system.	Implement alternating sequence management systems to prevent resistance.
C.3 Develop application schedules, methods in relation to economic thresholds.	Determine SPW population levels under various chemical and biorational control systems.	Determine relationship between SPW populations, chemical control, and yield for economic threshold.	Identify specific optimum controls in relation to SPW economic threshold.	Validate estimated economic threshold concept and insecticide use patterns.	Develop protocols for SPW economic thresholds and insecticide use on as-needed basis.
C.4 Insecticide resistance studies.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Develop standardized insecticide resistance monitoring systems.	Determine insecticide dose relationships, discriminating doses, and hormoligosis.	Initiate study to determine mode of action of insecticides.	Initiate studies to develop insecticide resistance management and outline area-wide pesticide rotation systems.
C.5 Genetics of insecticide resistance in SPW.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Begin construction of isogenic resistant and susceptible strains through back-crossing and selection.	Use RAPD and restriction mapping techniques to ID markers associated with resistance genes.	Isolate individual resistance genes in back-crossed lines and determine cross-resistance relationships.	Initiate studies to develop insecticide resistance management and outline areawide pesticide rotation systems.

C.6 Develop methods for application or delivery of materials to improve control.	Compare methods of application, e.g., aerial, ground, high volume air, and others for estimates of plant (especially under-leaf) coverage. Determine spray deposition (µg a.i./cm^2) and coverage for different application techniques, e.g., aerial, ground, electrostatics, chemiga-tion, air carrier sprays, etc. Relate efficacy to spray deposition and coverage.	Evaluate modified spray equipment, boom drops, nozzles, and arrangements; and chemigation.	Determine efficacy, with best coverage application equipment.	Verify best of the current state-of-the-art application equipment.	Determine need for continued research.
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Determine baseline information on existing natural enemies-quality and quantity.	Determine effect of various chemicals and biorationals on natural enemy populations and associated minor pests.	Compare rates, combinations, application technology on natural enemy populations.	Determine optimum and best materials and application technology to develop maximum natural enemy conservation.	Develop standard protocols for chemical control and natural enemy integrated systems for best control in relation to economic thresholds.

1 Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE D. Biocontrol[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Survey for and identify key natural enemies in various habitats and seasons.	Continue survey; culture and study reproductive biology of beneficial species.	Continue biological studies; determine effectiveness of species under various habitat and weather conditions.	Determine interactions among SPW, host plants and natural enemies.	Examine species and methods for exploiting selected natural enemies in crop systems.
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies..	Establish refuge plantings; colonize parasitoids; sample for and identify native natural enemies.	Continue sampling; test inoculative parasitoid releases; determine SPW/ parasitoid interactions.	Evaluate refuge plantings as field insectaries on larger scale.	Continue evaluation of most promising methods.	Implement and evaluate large scale conservation management systems.
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Collect, identify and import exotic natural enemies from specific habitats.	Continue collections; assess biology and host relations; develop rearing techniques.	Continue collections; determine habitat "fit" for each candidate; assess interactions with native species.	Conduct host range tests; rear, release promising natural enemies.	Determine adaptation of introductions and effects on SPW populations.
D.4 Determine natural enemy host selection processes and mechanisms.	Study mechanisms involved in natural enemy host foraging.	Study efficiency of host foraging mechanisms.	Determine factors affecting interactions of host foraging mechanisms, hosts and host plants.	Determine potential of implementing host foraging mechanisms in SPW population management.	Implement methodology developed into SPW management systems.
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Identify best candidates for augmentation based on selected attributes.	Develop laboratory rearing procedures for select species.	Conduct tests on technical feasibility of inoculating/ augmenting predator/ parasite populations for suppression of SPW.	Develop mass propagation and release procedures for selected species.	Conduct areawide suppression trials and continue developing the mass propagation, distribution, storage and release technology.
D.6 Determine effects of pathogens on regulating SPW populations.	Determine role in specific crops; develop culturing techniques.	Screen candidates for efficacy and effects on non-target organisms.	Evaluate for efficacy and persistence in small plots; develop formulations, evaluate for micotoxins.	Monitor dispersal and begin large scale field evaluations. Evaluate persistence and develop protocols for suppression of SPW populations.	Expand field evaluations and begin technology transfer.
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Laboratory screening for effect of pesticides on selected SPW natural enemies and develop baseline data.	Survey for geographic variation to pesticide exposure and select natural enemies with pesticide tolerance; identify pesticides that are compatible with natural enemies.	Challenge selected natural enemies to develop resistant strains.	Limited field trials to determine effectiveness and survival of resistant natural enemy strains.	Evaluate potential in large scale field trials.

D.8 Systematics of predators, parasites and pathogens.	Finalize taxonomist network; inventory species, literature, collections; survey NA fauna and flora; establish common curation techniques.	Continue survey; identify and voucher exotic material; implement protocols.	Review critical genera; establish limits of relevant species worldwide.	Describe new taxa, prepare keys, characterize phylo-genetic relationships.	Conduct molecular, biochemical, or other studies on target taxa.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE E. Crop Management Systems and Host Plant Resistance[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
E.1 Determine effect of traditional crop production inputs on SPW population development.	Investigate effects of irrigation, fertilization, and plant growth characteristics on SPW population dynamics.	Identify crop production methodology that may be a factor in SPW population development.	Determine mechanisms involved in crop production factors which greatly affect SPW biology, behavior, etc.	Determine possibility of exploiting or manipulating crop production methods as a factor in SPW management.	Develop methods that are grower acceptable to minimize SPW damage and maximize profits.
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Determine SPW reproduction, population development and factors affecting them on selected major crops and weeds.	Identify preferred cultivated and weed hosts and contribution to overall population density and SPW dispersion.	Determine interactions of cultivated host sequences and weeds on SPW population development and movement.	Determine potential of manipulating cultivated host sequences during growing season to reduce SPW populations.	Develop best strategy for cultivated host sequences that will minimize SPW damage to crops.
E.3 Determine effect of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SPW control methods.	Identify cultural practices in crop production systems affecting SPW biology and behavior.	Determine potential effectiveness of innovative cultural practices on SPW behavior.	Conduct studies to determine potential of cultural practices to affect SPW population development in the field and affect yield.	Identify cultural factors with greatest potential for adversely affecting SPW population development and improve yield.	Incorporate best potential factors into system and determine effect on SPW and crop net returns.
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Determine rapid, reproducible evaluation techniques for identifying resistance germplasms.	Apply developed methodology to identify resistant germplasm.	Use improved evaluation techniques to identify resistance mechanisms.	Begin to characterize resistance mechanisms and to identify chemical/ morphological components.	Continue characterization of resistance mechanisms
E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Collect potential sources of resistance germplasm.	Screen and identify resistance sources.	Quantify effects of resistance characters on SPW, virus, and associated plant disorders.	Determine interaction of selected plant types and SPW populations in the field.	Continue evaluation of selected plant types for management of SPW.
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Conduct plant breeding studies to incorporate resistance into acceptable plant types.	Continue plant breeding experiments to produce highest resistance levels.	Begin to transfer resistance factors into improved plant types.	Continue the transfer program.	Continue the transfer program.

1 Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE F. Integrating Techniques, Approaches and Philosophies.[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
F.1 Risk Assessment.	Identify a national evaluation panel to characterize risk assessment information needed for producers and the environment. Design risk assessment procedures for whitefly virus.	Interface with objectives for spatial analysis, network activity, ecosystem models and design risk assessment procedures for whitefly.	Operate risk assessment system. Validate risk assessment estimates. Expand to other pests. Collate multi-location results. Interface with IPM programs and crop loss assessment.	Technology transfer to existing institutional responsibility.	Support risk assessment system and develop management procedures.
F.2 Spatial Analysis and GIS.	Establish a national center to coordinate a national network of spatial analysis with GIS capabilities. Determine information needs for SPW.	Establish a network of user-information coupling participants. Input of spatial data. Look at other pest problems.	Run and validate system performance. Interface system with ecosystem modeling activity. Interface system with existing IPM networks.	Transfer technology to existing institutional programs. Combine GIS data bases.	Operate system under new framework of administration. Troubleshoot activities.
F.3 Ecosystem modeling.	Establish a National ecosystem model panel to identify scale and attributes of components. Interface with network.	Develop site-specific models in all participating states site-specific models. Define appropriate resolution of modeling activity. Address other pest problems.	Interface with spatial analysis. Couple crop model with spatial data.	Use model with spatial analysis capability.	Transfer activity to state institutions and assist in specific activity.
F.4 Networks.	Test and run NBCI bulletin board. Expand network to international dimension for biological control information exhibition. Expand written materials and workshop presentations. Bring GIS up on networks.	Teleconferences on SPW nationally. Expand to agricultural ecosystem management. Coordinate GIS with networks.	Teleconference SPW program internationally. Begin transfer of GIS to extension applications.	Continue to operate system. Continue transfer of GIS to extension.	Transfer national activities to permanent institution support.

F.5 Integrated Extension Programs.	Identify existing taskforce or action groups and link them into a communication network; written, elec-tronic, radio and confer-ences. Support and expand information network, newsletters, news articles, video conferences. Inter-face with appropriate National and State crop programs.	Develop procedures for data capture at local sites throughout the country and expand to other significant pests. Access spatial data and ecosystems models. Incorporate programs with existing IPM programs.	Maintain system and continue to expand other pests.	Maintain system.	Transfer system to permanent support such as State Department of Agriculture, Cooperative Extension Service, Commodity groups, private groups and troubleshoot system.

*U.S. GOVERNMENT PRINTING OFFICE: 1995-386-167/20018

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.